

Report No. UT-00.04

***I-15 CORRIDOR
RECONSTRUCTION
PROJECT
DESIGN/BUILD
EVALUATION
1999 ANNUAL REPORT***

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UDOT RESEARCH & DEVELOPMENT REPORT ABSTRACT

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16. Abstract <p>This report is the second annual report to be produced under a four-year project of evaluation and research into the I-15 design/build project. The Research Division of UDOT commenced this research project as partial fulfillment of the commitments made to the Federal Highway Administration (FHWA) when design/build was permitted for this project. The project was designated as a Special Experimental Project (SEP-14) project. The purpose of the evaluation is to collect and evaluate information derived from the process used in this project and provide this information to other agencies or entities interested in pursuing similar design/build projects in transportation.</p> <p>This report covers three areas of investigation.</p> <p>The first area covered by this report is a final evaluation of the design process used by Wasatch Constructors. The second is a follow up of the QA/QC program established by them for both the design and construction portions of the project. The third chapter covers innovative design and construction methods used on the project. The design evaluation is the last of a two-year evaluation of the design process used. The QC/QA is the second of four annual evaluations to be completed. The innovative construction methods is the first of three evaluations of this topic.</p>			
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I-15 CORRIDOR RECONSTRUCTION PROJECT

SPECIAL EXPERIMENTAL PROJECT 14

1999 REPORT

INTRODUCTION

On April 15, 1996, the Utah Department of Transportation (UDOT) requested approval from the Federal Highway Administration (FHWA) to use design/build for the I-15 Corridor Reconstruction Project under the provisions of Special Experimental Project 14 (SEP 14). April 15, 1997, UDOT issued a Notice to Proceed (NTP) to Wasatch Constructors to design and construct the project. Wasatch Constructor's design/build proposal for the base price plus construction and maintenance options was \$1.352 billion, making this the largest single highway contract (traditional or design/build) in the country.

An initial report prepared by UDOT titled "Design/Build Contracting Initial Report" covered the 14 month period from the middle of February 1996 to the April 15, 1997 NTP and described the acquisition strategy process (deciding on the type of design/build), the steps in the process, the development of the Request for Proposal (RFP), and the evaluation and selection of the successful proposer. A copy of the report is available from the UDOT Research Division

This 1998 report covered three areas of investigation. The first was a more detailed presentation of the selection process used by UDOT to select the contractor. This section was prepared as a separate white paper and submitted to the Transportation Research Board for possible publication in 1999. The other two areas covered by that report were evaluations of the design process used by Wasatch Constructors and the QC/QA program established by them for both the design and construction portions of the project.

This annual report contains the second year's review of the design and the execution of the QC/QA process. One chapter deals with the innovative construction methods used on the project. Future reports will examine this again to evaluate how well they have performed and to document changes made to those processes during the execution of the work.

SCOPE OF EVALUATIONS

This report is the second annual report to be produced under a four-year project of evaluation and research into the I-15 design/build project. The Research Division of UDOT commenced this research project as partial fulfillment of the commitments made to the Federal Highway Administration (FHWA) when design/build was permitted for this project. The purpose of the evaluation is to collect and evaluate information derived from the process used in this project and provide this information to other agencies or entities interested in pursuing similar design/build projects in transportation.

The scope of the study will cover several areas. The prior reports prepared by UDOT, and their consultants described the process used to develop the selection procedure and the RFP, the selection process used, documents the procedures that were followed and used by UDOT, an investigation and evaluation of the quality assurance/quality control program instituted for the project and the design process set-up by the design/builder to develop the detailed plans. This report contains a final evaluation of the design process, an annual evaluation of the QA/QC

process and an evaluation of the innovative design and construction methods used on the project. Depending on funding availability UDOT has directed additional investigations to be made into the following areas:

1. The Owner Controlled Insurance Program (OCIP) developed by UDOT for this project
2. The Public Relations Program used by UDOT
3. The QC/QA program will be investigated during several years to identify and evaluate changes that occur during the progress of the construction
4. The management structure established by UDOT to manage and oversee the project and compare that with the traditional process previously used by UDOT
5. Innovative construction methods, materials, and design techniques used on the project
6. Use of performance specifications
7. An assessment of the level of quality achieved on this project through the use of performance specifications.
8. The use of innovative materials and techniques used to construct fills and bridge abutments
9. The effectiveness of the partnering process used on the project
10. The Award Fee Program

Other areas may be examined as they surface during the development of the project and as directed by the Research Division of UDOT.

AUTHORS AND CONTRIBUTORS

The 1999 report was written based upon a series of interviews conducted with a number of individuals, both within the I-15 UDOT Team and the Wasatch Constructors design and construction teams. The innovative construction methods were developed by a team of evaluator's lead by Stan Postma, Project Manager. The team consisted of Jim Roberts, Deputy Director of Caltrans; Robert Brantley and Gray Wangelin, Senior Structural Engineers, Carter & Burgess, and Russell Moore, Senior Transportation Engineer, Carter & Burgess. The report was reviewed by Ben Watts former Director of Florida Department of Transportation and currently Director of Transportation for Carter and Burgess. The design process evaluation team was lead by David Stevenson, Senior Transportation Engineers, Carter & Burgess, formerly a design engineer with the Colorado Department of Transportation. David was assisted by Laurence Warner, Denver Regional Transportation Director, Region 6; Jim Roberts, Caltrans; Marvinetta Hartwig, Senior Transportation Engineer for Carter & Burgess and Stan Postma, Senior Transportation Engineer, Carter & Burgess.

The QC/QA portion of this report was prepared under the direction of Bob Whedon, Senior Construction Manager, Carter & Burgess. Jim Schroeder, Senior Transportation Engineer, and Stan Postma, Senior Transportation Engineer, Carter & Burgess.

We acknowledge the support and input from Doug Anderson, Project Manager, UDOT's Research Division, who provided guidance and editorial comments on the report. In addition a number of individuals from UDOT including the Executive Director Tom Warne; Project Director John Bourne and many of their employees were involved in interviews and guidance in review of the report. Contributions were also made by Wasatch Constructors Team through interviews and information provided to the Review Team. We acknowledge all of the support and input into the project and appreciate their assistance.

CHAPTER 1

Design Process Evaluation - I-15 Design/Build Project

INTRODUCTION

This report is the second and final review of the design process used in the I-15 Design Build project by Wasatch Constructors and UDOT. A preliminary evaluation and review of the organizational structure established for the design process was presented in the 1998 Annual Report prepared for this project. This second examination is intended to document modifications made to the organizational structure and process during the past year and to evaluate the process upon completion of the design phase of the project. Final design packages were submitted for all segments of the project in November 1998 and are being reviewed and approved by UDOT. It is anticipated that the final acceptance of all design documents will be completed by June 1999.

This report addresses the design process used on the project. Other reports have been prepared covering the selection process used by UDOT for selecting the design/build contractor, initial plan for the design and the quality assurance and quality control (QA/QC) processes used by Wasatch Constructors on the project. In addition to these reports UDOT intends to prepare evaluation reports covering topics such as the Award Fee, partnering, use of innovative design and construction methods and materials, the use of performance specifications, and public relation programs used on the project. Annual reports will be published which contain the results of the evaluations and a final report summarizing the entire project is scheduled for publication in 2002.

This report is divided into sections which address various issues identified during this review. At the end of this report conclusions and lessons learned are presented.

MANAGING THE DESIGN PROCESS

Notice to Proceed was issued to Wasatch Constructors by UDOT on April 15, 1997. The design process began in May 1997 and was completed by November 1998, approximately four months earlier than originally proposed by Wasatch Constructors. The design process produced nearly 14,000 plan sheets along with supporting specifications and design documents.

The following sections describe the staffing levels developed by both UDOT and Wasatch Constructors to complete their portions of the project.

Staffing Level Requirements (Wasatch Constructors)

After Notice to Proceed, Wasatch mobilized design staff using the resources of their prime design consultants Sverdrup Civil, Inc. and DeLeuw Cather, plus 18 subconsultant firms. The decision was made to locate as many of the staff in one central location as possible. A large office building was leased and equipped to house both the design staff, the construction administrative staff and UDOT staff. This location came to be called the 'Hub'. At its peak there were a total of 340 design staff on location in the "Hub" during the most intense design period. An additional 140 off-site engineers, mostly bridge designers, were used to accelerate the design

elements. The design team had difficulty attracting enough project bridge designers to move to the 'Hub' so a large portion of the bridgework was completed in outside offices. Additionally, some of the other work elements were completed in outside offices during 1998 when the design was accelerated, requiring additional design staff.

The 340-peak staff level was a substantial increase in the Design/Build Consultant's staffing level used during the proposal stage when approximately 75 design and construction personnel worked on the proposal for the six months during the selection process. Additionally, cost-estimating staff was provided by the three construction contractors involved in Wasatch Constructors.

Once the design packages were completed and submitted to UDOT for final approval, the Wasatch design staff was reduced. During the approval phase 40 to 50 design staff were maintained to make corrections to the final plans. After final approval is received on the plans, the design staff will be further reduced to an expected staff of no more than 20 for design support services during construction. In addition the designers are furnishing staff for the quality assurance and final design review groups. The staff is distributed as follows:

- Construction Quality Assurance (QA) – One for each of the three segments plus an overall QA Manager
- Final Approval Group – 8 to 10 people
- Field Design Group – 20 people

Staffing Level Requirements (UDOT)

The I-15 UDOT Project Team staffing levels of 55 to 65 people have remained fairly consistent throughout the duration of the project. The peak staffing period occurred during the right-of-way plan development and acquisition process. During the major design phase about 1/3 of the UDOT staff was involved in the design oversight process. As the design activities have concluded the staffing has evolved to include more construction personnel. As of June 1999, about half of UDOT's staff are responsible for construction oversight and the rest are involved in administration, management and design.

Due to legislative limitations, UDOT was limited on how many staff could actually work on the project. Since UDOT could not increase their total number of permanent full-time employees to work on this project, UDOT hired several consultants to assist and support them on the project. Parsons, Brinkerhoff, Quade and Douglas (PBQ&D) was hired as the primary consultant to provide support for UDOT's staff. UDOT also hired other firms including a public relations firm and testing laboratory. Together the group functions as a fully integrated I-15 Project Team. Many of the team assignments have been composed of a mixture of UDOT and subcontractor staff, depending upon the requirements of the assignment. However, all management and construction oversight is completed by this team made up of UDOT and consultant staffs. PBQ&D assists with administrative, technical design reviews, contracting, right-of-way, utilities, construction oversight and railroad coordination activities. UDOT and another subconsultant handle public relations activities. Overall, approximately one-half of the I-15 Project Team is comprised of UDOT employees with the rest made up of consultants.

Procedures

The project has allowed for numerous procedural innovations, including financial incentives that are a key component of the Design/Build contracting process. A prime example of a significant procedural change has been the use of a Task Force process for review in place of the more traditional detailed review process used by most owners. Detailed reviews and QC/QA roles were assigned to the contractor with audits performed by the owner to monitor compliance. Location of the design, contractor and owner staff at one single location was another significant procedural change not previously used by UDOT. Use of performance specifications was also a significant departure from normal procedure.

UDOT and Wasatch used a Task Force process to provide direction and review to the design teams. The Task Force meetings were held each week and consisted of representatives of the Contractor and his designers, UDOT and FHWA. UDOT staff attended each session and provided input into the design at this stage. In these meetings design approaches, questions and criteria were discussed and decisions made as to acceptable solutions. Minutes of these meetings were prepared and reviewed by all present. It was during these review meetings that UDOT staff was able to monitor what the contractor and his designer's were doing and review design criteria and solutions. They also provided input on any design issues. Some Task Force meetings were discipline oriented where a design criterion was discussed. Others were segment related where specific segment related design issues were discussed and resolved. Copies of plans, specifications and design details were made available to all parties prior to the Task Force meetings so that they could be examined prior to the meeting and any questions addressed during the meeting. Copies of the minutes serve as the record of the decisions and are still referred to when field questions are encountered.

Another procedural example was the sharing of value engineering savings with the Design/Build Consultant. The Design/Build contract allows the Contractor to receive 50% and UDOT to retain the other 50% of any savings achieved. The contractor agreed to share a quarter of their portion with the prime design consultants. However, these saving incentives were not shared with subconsultants to the prime design team.

Physical Facilities Requirements

UDOT, the Contractor and the Designer were all located in the same building referred to as the "Hub". From everyone's perspective, this was crucial for the success of the project. This co-location enhanced communication among all parties and facilitated in coordination; i.e., time was not wasted sending faxes, commuting to meetings, trading telephone calls, etc. Everyone was also connected electronically through the same computer network system, although secure areas were provided for each party. If there were any questions, the answers were just a few steps away.

During the peak period of design, approximately 140 designers were located off-site. Consultants were used throughout the country, which made communication more difficult. Not only was it harder to keep the off-site designers up-to-date with the latest facts and information, they did not have the benefit of easy access to UDOT or the Contractor. This caused more time to be spent by the on-site design and management groups to coordinate these off-site work tasks. Since there was no more space left in the building to house additional designers once it was

decided to accelerate the design process by four months, this additional staff was allowed to be added at remote office locations.

UDOT's I-15 Project Team and management staff were all located in the "Hub". This was viewed as critical in maintaining the aggressive design schedule by reducing delays in going back to headquarters to obtain approvals or support. UDOT's project staff was authorized to make most of these decisions. They were also involved on a day-to-day basis and were available for questions and coordination with the Wasatch Constructor staff.

Management Requirements

The contractor chose to use a system called Earned Value Reporting to control his operations. Because the contract called for a lump sum bid for the majority of the work it was viewed as necessary by the contractor to break the project into smaller sections. Contractor staff felt that this was absolutely required to effectively manage this kind of project. Activities were tied to milestones with each milestone having work-hours associated with them. Increments of 40 hours were used. The system was integrated to include both design and construction activities. The contractor and his engineers used electronic time card reporting so the hours spent on the project were tracked weekly (i.e. "real-time"). In addition, overhead direct costs were paid as a lump sum to reduce the amount of tracked cost items.

The Partnering Program was viewed by both UDOT and Wasatch as essential on this project. UDOT recommended an extensive partnering process as part of the contract requirements. The contractor responded to this recommendation by establishing a formal process for partnering, including regularly scheduled partnering meetings with UDOT at several management levels. The partnering escalation process was very important and was used extensively to resolve project concerns. However, during the design process, there was only one single instance when an issue had to go to the top of the escalation process. The reason given was that it was of a legal issue dealing with wage determination that could not be addressed by anyone other than the executive director of UDOT and his Wasatch counterpart.

To manage the design efforts, procedures to track drawing lists, master plan sets, revisions and versions were established. The Task Force groups used detailed meeting minutes to keep track of issues and decisions. Design issues were discussed in weekly meetings to ensure their timely resolution and maintained on a list until resolved.

To manage the labor expenditure, the design/production manager had a financial manager counterpart to track this information. The design/production manager was responsible for assigning resources and meeting schedule. The financial managers were responsible for cost budgets. However, the production managers were ultimately in charge of ensuring that the work was completed within the allotted funds.

Computer Automation Requirements/Software

The Design Group used a single design and drafting software. This was a requirement for everyone involved in the project. The selection of the software was based on UDOT's

requirements to ensure compatibility with their own system. MicroStation and InRoads was the actual software used for the project.

A CADD Task Force was established at the beginning of the project to address CADD issues. To get this system up and running was fairly easy and not a schedule issue.

A program called *Resymbol* (a Sverdrup program) was used to make sure the CADD files met project requirements for drafting consistency. This program was used to review all submittals, especially those from external consultants. For the most part, this process worked fairly well. However, in one instance it took approximately 360 hours to fix one of the submittals and bring it into conformance with the CADD standards.

In addition to the design software, the Design/Build Team used *Expedition* to manage the project's electronic communication, including scheduling and timely distribution of the meeting minutes. This system was also used to track all communications.

QC/QA Process

Wasatch was required to develop a Design Quality Management Plan (DQMP) and have it approved by UDOT. The initial development process was a big challenge requiring several months to complete. Once developed it took three to four months for Wasatch to fully implement.

Wasatch's Quality Assurance Manager performed over 7000 audits in 20 months. The contractor had one single person assigned to perform all of the QA audits. These audits consisted of checking that reviews and procedures outlined in the DQMP had been completed and documented and that the QC process had been completed.

UDOT conducted audits during the design process on a weekly basis. On average, UDOT conducted between 9 and 30 audits per month as part of their weekly oversight reviews. Their goal was to audit 10% of all designs.

UDOT used a two pronged approach to provide design oversight. These consisted of:

1. Audit of the Contractor's actual QC/QA process and comparing it to the DQMP.
2. Weekly Task Force meetings with the contractor's personnel to discuss design issues and perform oversight review of plans and specifications.

Figure TS1 shows a graph of the number of oversight reviews conducted monthly between December 1997 and December 1998. They averaged about 115 reviews per month.

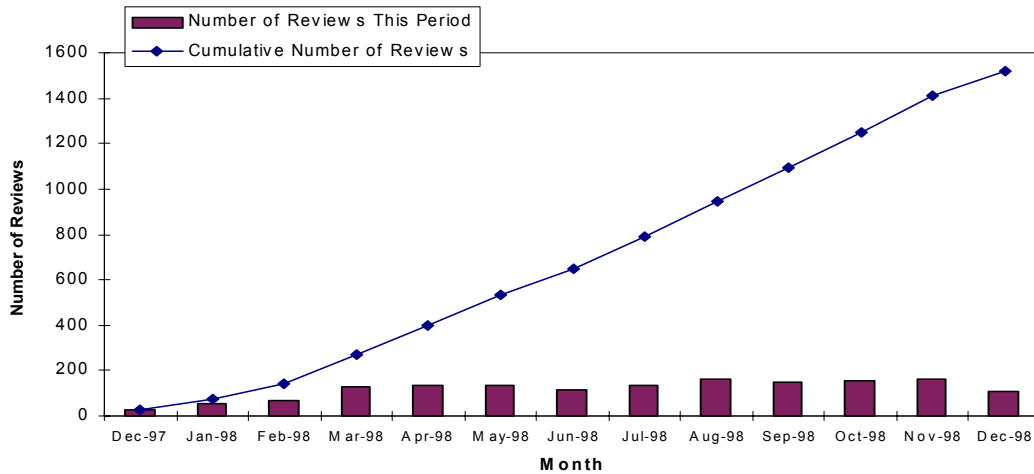


Figure TS1 - Number of Oversight Reviews Performed

UDOT implemented an audit tracking file that began in December 1997 to document how many audits were performed and their status. No detailed records of the audits prior to December 1997 were kept. UDOT's involvement was basically limited to weekly oversight audits. Detailed reviews were limited to possibly less than 5% of what would normally be performed by an owner. Figure TS2 shows the extent of audits performed during the design process.

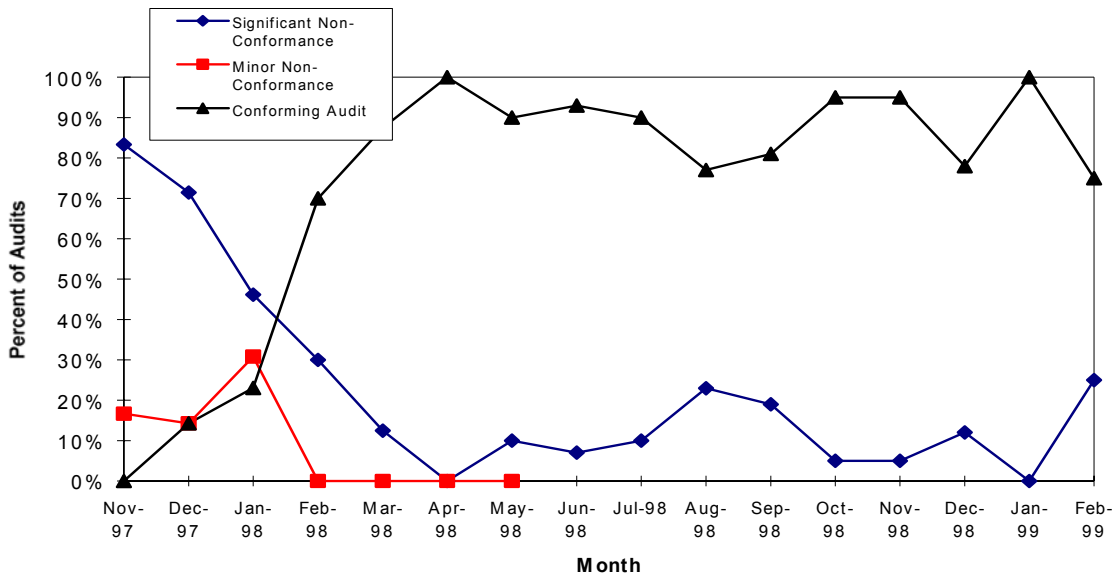


Figure TS2 - Design Quality Audits

UDOT's Auditor reviewed Wasatch audit records of the QC/QA procedures and then prepared a report on non-conformance issues. UDOT's Technical Support Manager then evaluated the significance of non-conformance issues. Major non-conformance findings that could affect the award fee were returned to Wasatch for response. Monthly audit results were considered in the Award Fee evaluation.

Some non-conformance issues were raised on non-critical issues such as failure to use the exact process of review specified in the DQMP. These issues were generally remedied by additional training. The stringent process established by the Contractor created several of their own non-critical and non-conformance findings. A more simplified process would still have been acceptable contractually and may have avoided some of the non-conformance issues. However, once the plan was adopted by Wasatch, UDOT was obligated to enforce the process in the audits.

Wasatch required that completed QC process checks were made at 30%, 65%, 90% and 100%. The level of the QC process checks for each of these submittals were as if the plans were 100% submittals. This was time consuming and beyond the contract requirement of 50% and 100%, but the Contractor still required that QC be done on all submittals.

The QC process was generally viewed as adequate. There was difficulty in the beginning getting everyone to follow the procedures and is reflected in the data shown on Figure TS2. This was rectified by additional training of the Design/Build Team on the procedures and requirements of the QA plan.

SUBMITTALS AND REVIEWS

Submittals

There were design reviews made at the 30%, 65%, 90% and 100% design level. The contract required only two formal reviews, one at approximately 50% completion of design and the final 100% with a submittal. The other reviews were proposed by Wasatch as progress reviews and were made a part of the "Over the Shoulder" review process. Division of the project into design segments by Wasatch required 13 separate final submittals: ten design section submittals, one corridor wide (standard plan) submittal, one Automated Transportation Management System (ATMs) submittal, and a final/sealed plans submittal.

The number of sheets per section submittal varied from 400 to 1500 sheets. The total number of sheets submitted was approximately 14,000. There were also approximately 350 standard drawings produced.

In addition to these submittals, there were additional submittals for constructability reviews and staged construction. These varied throughout the process and were generally a part of the total submittals.

Reviews

For the formal final submittal, the ten design section submittals were scheduled one week apart with allowances made for Christmas and New Year's Eve holidays. By contract UDOT agreed to complete a one-week review and return written comments to be followed by a subsequent Comment Resolution Meeting. The Design Group was then required to resubmit final corrections two weeks later. Because of the many comments made for all sections, a final submittal was made at the end of the review period to ensure all issues were adequately addressed.

UDOT purposely staffed the Oversight Team to require that the Design/Build Consultant perform the detailed reviews normally performed by UDOT. UDOT did not have the staff and time to complete these detailed reviews. It was also intended that the Engineer of Record assume the detailed design review responsibility when the documents were signed. UDOT performed reviews to determine fatal flaws in the process or methods to be used, but not the detailed technical reviews.

For the final review, each section averaged 200 comments. This was more than what the Design/Build Contractor expected. About half of these comments were editorial with no additional design action needed. UDOT also commented on items that had not been commented on previously even though it was anticipated that only an assurance check would be performed to ensure that previous comments had been addressed.

For the final review submittal, the Design/Build Team submitted one package weekly beginning the end of November 1998 for a total of twelve submittals, with the last one scheduled for mid-March 1999. A thirteenth package is intended for a 'clean up' submittal at the end of the process to incorporate any comments that effect all of the submittals. After the final review, UDOT will send a final letter of design approval although the design will not be formally accepted until after the final construction is completed and accepted.

The "over-the-shoulder" review process used by UDOT on this project was a new concept for them. At first it was expected that this would result in opportunities to only do a cursory review of the project. As it was implemented, and using the Task Force meeting process, this resulted in having UDOT staff intimately involved in the design process at much earlier stages than is typical of a design project. The Task Force meetings offered opportunities to have UDOT get involved at very early stages of development of criteria and plans, where decisions were made as to how to proceed. With this exposure to the design it became much more efficient to review the project because UDOT staff had been involved throughout the process and were intimately familiar with the design that was occurring. This daily involvement with the design team resulted in having UDOT staff very well informed about the design and in agreement with the design decisions that were used on the project.

Of the 142 bridges on this project, 134 were designed by the Design/Build Team. The other eight bridges were sealed plans included as part of the original bidding documents. The schedule for bridge review was different from the roadway reviews. Each bridge had a two-week final review by the two person UDOT bridge review staff.

Field Design Changes

There have been approximately 150 field changes per month during the construction period. This number has remained fairly consistent throughout the project. Field changes occur in three types.

- Field Design Change (FDC): a change initiated in the field not to build the feature as designed or to make a modification to meet either field conditions or equipment and labor capabilities.
- Request for Information (RFI): Clarification of design.
- Nonconformance Evaluation (NCE): Designer input on how to resolve non-conforming work without removing and replacing. The Quality Control Group (Field or Design) initiates a NCE.

Many of the field changes were associated with embankment, surcharge and construction staging issues. Figures TS3 through TS6 quantify some of these changes as of March 1, 1999.

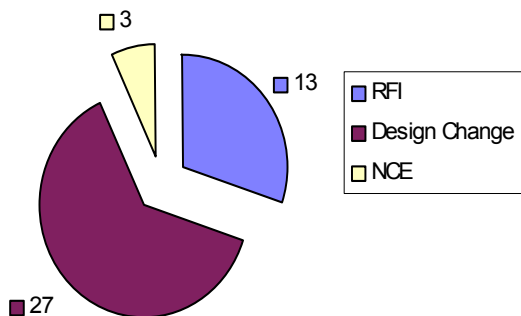


Figure TS3 - Field Design Memos Downtown Segment

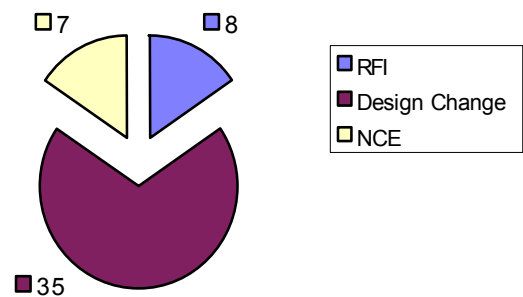


Figure TS4 - Field Design Memos Jordan Segment

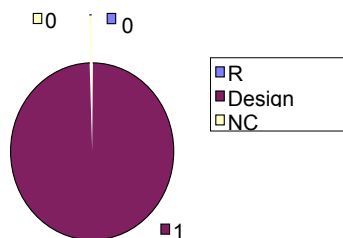


Figure TS5 - Field Design Memos ATMS Segment

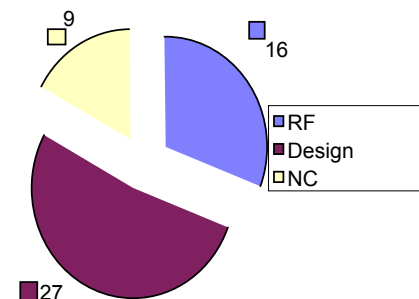


Figure TS6 - Field Design Memos Cottonwood Segment

A process to handle plan changes during construction was developed. It was important that UDOT stay involved and informed regarding field changes. One way of keeping UDOT up-to-date was to have weekly post design service meetings to discuss field design changes. If UDOT determined that construction was not in conformance, they issued an Owners Monitoring Notice (OMN). These items were tied to criteria in the contract and given to the Quality Control Group (QCG). If the QCG agreed, a written Nonconformance Evaluation Report was provided. The item was then revised, removed and/or replaced. If the Quality Control Group disagreed, the problem escalated. This process was usually resolved between the Contractor and UDOT with very few instances escalating. This process was developed after initiation of the project and replaced an earlier problem resolution system that did not function satisfactorily.

Technical Agreements

Wasatch and UDOT, as a result of a separate Memorandum of Understanding (MOU), further expedited the change process by agreeing to use Technical Agreements. The MOU stated that the contractor was allowed to make changes to the contractor's proposal, performance specifications or standard specifications as long as UDOT agreed that the changes were equal to or better than the original contract requirements. The Contractor requests a change, and if UDOT concurs a Technical Agreement is developed documenting the change. Once signed, this becomes part of the contract and modifies the original proposal. This allowed technical staff to proceed with reasonable changes and avoid delays associated with lengthy approvals. Figure TS7 reflects how many Technical Agreements were processed during 1998.

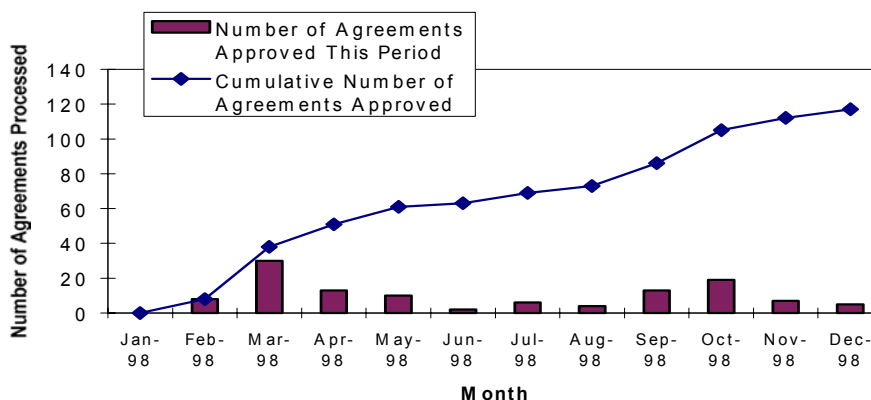


Figure TS7 - Approved Technical Agreements

EARLY ACTION ACTIVITIES

Utilities

Early identification of existing utilities was very helpful. UDOT prepared master agreements with the utility companies prior to the Notice to Proceed on the Design/Build project which identified who would design, review and construct utility relocations and betterments, and who would pay for the work items. This was established before the project began. The Contractor

then negotiated individual utility construction work agreements during the Design/Build stage. However, UDOT is still responsible for all the final contracting and payments.

There were approximately 1500 utility crossings, with 800 conflicts identified for relocation. The Contractor generally performed design and construction with the utility companies reviewing and approving plans and construction. The Contractor hired two separate engineering companies who had previously worked with the utility companies to complete the designs in accordance with the utility Companies requirements. Two utility companies did their own design and construction - US WEST and Utah Power. These companies had previously commenced advance work on their own facilities and wanted to complete their own work.

The project paid for all conflicting utility designs and relocations. The cost of utilities was bid as a Lump Sum with the burden of delays shared equally between UDOT and the Contractor. The Contractor was reimbursed for all identified utilities that were impacted. If the Contractor was able to reduce the number of relocations, the Contractor's reimbursement was not reduced which provided an added financial incentive to minimize conflicts. Betterment to the utility's facility was a utility company(s) fiscal requirement and was not a part of the project's expense. Payment for betterments was made by the appropriated utility through UDOT to the contractor.

Right-Of-Way

UDOT was responsible for all right-of-way acquisition and began acquisition approximately nine months prior to issuing the Notice to Proceed. The identification of the required acquisition properties was provided to the contractor prior to the Request for Proposal. UDOT committed to acquiring one-third of the parcels prior to the Notice to Proceed and the balance on a schedule provided to the Contractor. Right-of-Entry was obtained for the remaining parcels so the Contractor could proceed with work prior to the completion of the acquisitions. A total of 350 properties were acquired.

The Contractor was responsible for obtaining all construction easements, including those required for staging areas and haul roads. He could however, elect to have UDOT acquire these and reimburse UDOT for any costs. He elected this option.

There were problems encountered during design with the right-of-way as shown on the plans. Apparently, the detailed right-of-way research was performed on the areas where anticipated parcels were required by UDOT. In other areas the right-of-way was shown through a minimal amount of record research and was shown primarily as a line on a drawing. This was a concern to the design team in trying to confirm that they were staying within the right-of-way as they were completing design throughout the corridor. Wasatch was responsible for the cost for any of the additional right-of-way required beyond that which was committed to by UDOT. It would have been better for the designers had UDOT tied down the right-of-way information more precisely on the drawings, either through reference monuments or ties to section corners so that the designers could have more confidence in the precise location of the right-of-way shown on the plans.

Drainage

Quantities of permissible discharge flows (e.g., discharge restrictions into the Jordan River and other channels) were established by UDOT prior to release of the Design/Build Request for Proposals. UDOT verified that these quantities were reliable for bidding and construction purposes and documented them in the Project Drainage Report. Any agreements and permits required were completed by UDOT prior to or during construction.

Mapping

UDOT furnished a complete digital terrain model with contours of the entire corridor. This was done prior to the award of the project. This was available in digital form to all proposers during the development of their proposals. The Contractor thought this was a valuable resource for all of the design teams in that they could rely upon solid and accurate mapping information. The Contractor's consultants did some supplemental surveying to confirm specific locations but generally the mapping furnished with the design was adequate for most of the design work.

Hazardous Material

Hazardous material investigations were performed prior to the Request for Proposal. From this investigation, UDOT established a budget and requested bids on quantities from the Contractor. The hazardous material quantities were bid using unit prices that reduced the risk to the Contractor. These unit prices were renegotiated if estimated quantities were found to be significantly different than estimated. Figure TS8 reflects charges as of the end of 1998.

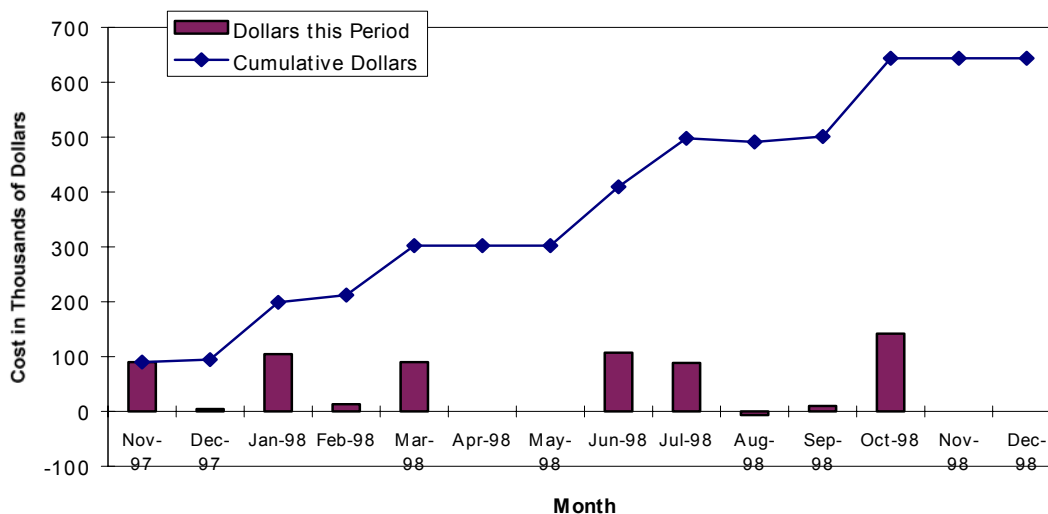


Figure TS8 - Hazardous Materials Remediation

Permits

All environmental permitting was completed by UDOT prior to the award of contract. By contract UDOT required that the Contractor conform to the conditions of the permits. Permit information was provided to the Contractor at the time of proposal.

Geotechnical Investigations

Extensive geotechnical investigation information was provided by UDOT to each team prior to award of contract. This consisted of an extensive amount of exploration work, soil log information and all testing that was accomplished by the geotechnical firms. No interpretation of the information was provided, however. This was left up to the design team. The expectation was that this would expedite the design of the project because they would already have the geotechnical information needed for design.

Generally the geotechnical information furnished was valuable to the design teams. They did perform additional investigations beyond what was furnished but felt that the information provided was also of great value.

One of the design teams indicated that much of the geotechnical investigation work performed for the viaducts was not as useful as it could have been since the contractor decided to relocate piers. This invalidated the site specific geotechnical investigation performed at the locations of piers based upon UDOT's expectations of where they would be located.

The contractor has relied extensively upon the use of wick drains, mechanically stabilized earth (MSE) walls and geo-foam construction on the project to try and meet some of the geotechnical challenges of the project. Wick drains were used under many of the fill locations to accelerate the consolidation of soils and shorten the construction time staged. Staged MSE walls were used extensively to help compensate for the expected large settlement that would occur on the high fills and also to accommodate staged construction. They used geo-foam in locations where it was determined that consolidation would not be achievable within the time frame required or where there were conflicts with utilities and relocating the utilities would be too expensive or difficult. The purpose of the geo-foam was to reduce the weight of the fill thus decreasing the consolidation time that could be expected under the fills.

Railroad Work

Although UDOT negotiated the original corridor-wide master agreement, all railroad permitting activities are being completed by Wasatch. Any costs incurred due to delays by the railroad will be shared equally between UDOT and the Contractor.

PROBLEMS

Value Engineering

The potential benefits of value engineering were limited on the project. The contractor's incentive was time driven. Any modification to the proposed plan that resulted in requiring more time to construct the feature was treated as a disincentive to use value engineering. The contract provided an incentive to use value engineering on alignment changes by agreeing to share any savings with the contractor on a 50/50 basis. The Contractor, in turn, agreed to share a portion of his savings with the design consultant (1/4 of his savings). However, the subconsultants to the prime design team were not included in this incentive. Also, because a lump sum contract was used on the project the incentives for value engineering were limited to changes affecting the alignment.

Because the project is so schedule driven the effects of value engineering were reduced in practice. Any value engineering change was evaluated on both the basis of the costs that could be saved and the impacts to the schedule any changes would require. Generally, changes resulting in an extension of the schedule were not implemented, even if there was a cost savings associated with them. Delays to schedule were viewed as more critical than savings in costs. Since subconsultant design teams were not directly rewarded for value engineering efforts they did not emphasize value-engineering solutions.

Development Of Standards And Plans

Wasatch developed standards and plans that were intended for use by designers in completing the plan sets. More than 350 standard plans were developed for commonly used details of the construction. The standards presented the process and quality standards intended for each plan set to provide uniformity in design and assure that similar situations were treated the same way for ease in construction. Unfortunately, the development of the design standards and standard plans occurred at the same time that many of the designs were begun. This resulted in many changes to those early plans once the standards were developed. This could have been avoided or reduced had they waited until the standards had been completed. Wasatch had thought that they could use many of UDOT's standard details in their design but discovered that many of the details they wanted to use had either not been developed by UDOT or Wasatch wanted to use a different detail.

Wasatch indicated that they probably could have saved some time and costs had they concentrated early in the project on development of these design standards and plans. This would have necessitated some delay in the start of design and Wasatch had elected to begin design as soon as they could and make the changes once the design standards were fully developed. This did not seriously affect the schedule and Wasatch still completed the design ahead of their planned schedule but it did result in some reworking of the plans.

Performance Versus Prescriptive Specifications

UDOT prepared several performance specifications for use on this project. They also referenced their standard specifications, which are prescriptive, for several items not covered by the performance specifications. Wasatch had some difficulty in using this mixture of specifications

because they felt that the prescriptive specifications limited their ability to provide innovative solutions to resolve problems. They much preferred the performance specifications because these results oriented specifications permitted the contractor to accomplish the design or construction in a manner that best suited the equipment, material or methods he wanted to use. Wasatch recommended that owner's consider providing as much flexibility to the contractor as possible to permit him to use innovative means and methods to complete his work.

Constructability Reviews

UDOT had expectations that they would benefit from use of constructibility reviews during the design process resulting in significant improvements in the designs. UDOT found that this did not occur as often as they expected. Also, subcontractor designers were often not included in these types of reviews lessening their potential benefit.

Engineer Of Record

UDOT expressed some concern about the fact that the services of the engineers of record who prepared, stamped and sealed the drawings were not extended through the construction of the project. Generally, the engineers of record left the project after design was completed. The result is that field changes are reviewed by the construction support group and changes made without being able to consult with the engineer of record who prepared the original drawings. One recommendation that UDOT made was that on future contracts the engineer of record be required to remain on the project in a construction support role through the construction phase.

Accelerated Construction Schedules

One of the major conflicts noticed between the designer and the construction personnel has been the use of accelerated construction schedules by the contractor. Often times the contractor required early submittals on the design of walls, for example, when the design had not been developed completely enough for the designers to be confident about what the wall designs required. This caused difficulty in releasing early construction items to the contractor in the time frame that he wanted. This placed all of the retaining wall designs on the critical path schedule. The design teams tried to standardize many of the wall details and designs to attempt to alleviate some of this problem but were not able to resolve all of them. Universally the designers indicated they would have preferred more time to more completely develop the retaining wall designs prior to releasing them to the contractor. This has required that some walls be modified in the field after some problems arose with walls constructed in the wrong location. Fortunately it has not proven to have a significant negative impact on the project.

LESSONS LEARNED

Consolidated Office Location

Having all of the Design/Build Team located in the same location was vital in meeting project schedule. Generally, the consensus among UDOT and Wasatch was that there was no other way to do this project on this time schedule. Time was not wasted transmitting faxes, commuting to meetings, trading telephone calls, etc., since everyone was connected electronically. The Contractor stated that this should be a requirement of the contract. In addition, the Contractor should plan for expandability of office space. With UDOT, the Contractor and the Design Team

all located within the same location, it was very easy and efficient to address questions and issues.

Advantage Of Task Force Meetings

It has helped to have UDOT be able to “speak up” as a problem was encountered. This allowed an issue to be dealt with before it became a problem. The Contractor acknowledged that having the Owner’s acceptance/approval as things went along was helpful, and also reassuring that things were proceeding as expected and not waiting until the end of construction. The Task Force meeting process facilitated this interaction.

Preliminary Design Level

Both UDOT and the contractor felt that less preliminary engineering could have been done for this project. However, the design group felt the level was sufficient. The biggest problem associated with the level of design was with the “sealed” plans included in the project. Because these plans were a complete sealed design, UDOT assumed the responsibility for the design. There were field changes that had to be made to the plans and this complicated the Change Orders process. The owner has recommended that sealed documents not be included in future projects because of this.

For the Design/Build process, basic geometry and typical sections needed to be established. This project also had the requirement of staying within the identified right-of-way. Any changes to the basic geometry and impacts that required additional right-of-way would then become the responsibility of the Contractor for acquisition. This approach has worked effectively for this project thus far.

Use Of Design Standards And Standard Plans

Earlier development of the design standard and standard plans used by the Contractor could have resulted in greater efficiencies in time and money. These were used as the basis for the majority of the design. Problems occurred when the early phases of design, which were completed concurrently with the development of the design standards and standard plans, needed to be revised when changes were made to the standards and plans.

Performance Versus Prescriptive Specifications

The challenge of a Design/Build project is finding the right balance of the Contractor’s capabilities and the Owner’s responsibility. Specifications need to be written as end product specifications where possible, not prescriptive. This provides the Contractor more flexibility in the construction. Specifications should provide a toolbox approach to allow for innovation by the Design/Build Contractor.

Audits

It is important that an audit tracking system be set up at the beginning of the Design/Build process. It took UDOT several months to set up their tracking system. Prior to the system being set up, there was no record of the audit process for approximately six months of design. At the beginning of the Design/Build process, what the Owner wants checked should be clearly defined. This would provide an effective baseline for establishment of the Contractor's process. On this project, the Contractor completed detailed reviews of all work products and not just those being formally submitted to the Owner or actually used in the field. Some effort could have been reduced had Wasatch adopted a different audit policy.

The Design/Build Contractor's QC/QA program was more extensive than required by contract -- especially on earlier submittals when full QC/QA checks were completed when not really needed. UDOT only required complete reviews for 50% and 100% design completion. The Contractor required completing reviews at 30%, 65%, 90% and 100%. The general consensus was that they would probably not perform as detailed of a program for future projects.

Reviews

The contract provided for a seven-day turn around by UDOT on the final plan submittal. This time frame was not sufficient. More time should be provided for this process.

The Task Force approach, and weekly Comment Resolution Meetings, have been a significant benefit to the project's success. This has allowed for multiple agency involvement during development of the design and resulted in less comments and changes at later stages.

Staggered submittals should have been required in the contract. The Contractor worked with the I-15 UDOT Team on this, but were not required to do this by contract. However, for this project it has worked out.

Because of the magnitude of the number of bridges, UDOT felt there should have been more people involved on its part to review the bridges.

Processes for effectively coordinating field changes need to be established early. This process needs to be in place at the beginning of the project.

Impacts Of Time Driven Schedules

Schedule was the major driving force in design and seemed to limit much of the design innovation. Although there may have been a better way to accomplish some elements, they were not considered if it meant compromising time limits. This is largely due to the fact that the award fee is primarily structured around meeting the schedule.

Owner Involvement

UDOT has been extremely committed to this project and the Design/Build process. They have actively attended all meetings and have participated throughout. UDOT has been very proactive thinking out-of-the-box and coordinating with the on-site staff. This has helped expedite the design schedule and issues resolution.

CHAPTER 2

Annual QC/QA Program Report - I-15 Design/Build Project 1999

Introduction

This is the second of a series of annual reports on the QC/QA process being used on the I-15 Design/Build project. This report covers the period from July 1998 to July 1999. Other reports have been prepared covering the selection process used by UDOT for selecting the design/build contractor, initial plan for the design and design processes used by Wasatch Constructors on the project. In addition to these reports UDOT intends to prepare evaluation reports covering topics such as the award fee, partnering, use of innovative design and construction methods and materials, the use of performance specifications, and public relation programs used on the project. Annual reports will be published which contain the results of the evaluations and a final report summarizing the entire project is scheduled for publication in 2002.

The project was begun in April 1997 when the contract for the design/build services was awarded to Wasatch Constructors (Wasatch). The report prepared last year presents a discussion of the organization set up and used in the first year of the contract. The QC/QA program was developed during the first year and certification under ISO 9001 was obtained during that period of time.

This report covers the first full year of implementation of the QC/QA program by the contractor. During this period of time the construction has progressed to the approximate mid-point in contract time and about sixty six percent of contract value. Also during this time period the design services portion of the project were essentially completed. Construction activity included the closing of one-half of the former facility, removal of the downtown and I-80 viaduct connections, completion of one new interchange and partial completion of several other interchanges. Approximately one-half the earthwork for embankment construction was completed, approximately 20 bridges were constructed and several lanes of concrete pavement were begun. Most of the utility relocation work had either been completed or was being completed as of the date of the evaluation.

Two QC/QA programs were developed for the design/build project. The first was developed and used to monitor and control the design process. The second deals specifically with the construction activities. The QC/QA process used in design is covered in a separate report dealing with the design process. Reports were developed in 1998 and earlier in 1999 which describe the QC/QA program involved in the design process and the “over the shoulder” review process used by UDOT. The reader is referred to those reports for a discussion on the design QC/QA program.

This report deals specifically with programs used for the construction activities. This report serves as one of four evaluations of the QC/QA program, which will be completed during the construction of the project. Changes to the program, which have occurred since the project began, are documented and evaluated. This evaluation also includes an assessment of the effectiveness of the QC/QA program to address quality control issues of the project.

BACKGROUND AND PROJECT STATUS

Background

This project is the largest design/build project under contract with a State Department of Transportation. Selection of a design/build team was made under conditions known as “best value” selection. The process of selection was developed by UDOT specifically for this project.

The selection process began in March 1996 with issuance of a notice of interest in the project. A contract was awarded to Wasatch Constructors on April 15, 1997 and a notice to proceed immediately given. The contract called for the design/build team to both complete design and construct 17 miles of new freeway system to replace an existing facility. The contractor was required to maintain a portion of the traffic carrying capacity of the former facility as the new facilities are constructed. A completion deadline of the end of 2001 was placed on the contract to permit the facilities to be fully open and functional within 4 ½ years to reduce the inconvenience to the driving public and also accommodate the 2002 Winter Olympics to be held in Salt Lake City in February 2002.

Design/build was chosen as the contracting vehicle because it was felt that this was the only way to accomplish the project within the allotted time limit. UDOT had not used this process on a large-scale project in the past and so all of the contracting procedures were developed specifically for this project. They based some of their process on similar successful transportation projects underway in Southern California.

Current Contract Status

The contract for the project totals \$ 1.325 billion as awarded. This included a lump sum contract for \$1.018 billion and the balances are unit cost bid items specified in the original contract. The project completion date was set as October 15, 2001.

As of the date (summer 1999) of this evaluation the contract status is as follows:

- Time is 50 percent complete
- Costs are 68 percent spent
- Construction is just under 50 percent completed as estimated by UDOT

Type of Work Activities

During the first year of the contract, through 1998, most of the construction activities consisted of demolition of portions of the existing freeway and construction of embankments used for surcharge and settlement control. There were some facilities, which had been designed by UDOT that were begun, and some completed during this time period. An example is the new interchange that was completed at 600 North.

The type of construction activity is beginning to change from demolition and earthwork to structures and pavement elements. It is expected that by the end of 1999 traffic will be transferred to new pavement and new bridges in preparation for demolition of the balance of the old system. The major freeway interchanges at I-80 were removed in the first two years and structure work to replace these has begun and will continue in the next two years. The viaducts

leading into downtown Salt Lake have also been removed and new replacement structures begun. The construction activity emphasis is changing to less earthwork and more structure and pavement work. This will continue as more of the embankments are completed. Correspondingly, the QC/QA program will also shift to more structure and pavement oriented activities, where it has focused on earthwork for the first two years. This will result in a change in some of the needs for staff technical training and quality control requirements.

CHANGES TO ORGANIZATION IN LAST YEAR

Wasatch Constructors Staff and Organization

Originally Wasatch Constructors allocated a significant portion of their QC/QA staff to the quality assurance (QA) group with a smaller staff assigned to quality control (QC). This was done with the expectation that acceptance testing would be performed by the QA forces. This was modified extensively in April 1998 and more of the staff re-assigned to the QC role.

During this past year acceptance testing has been assigned to the QC functional role. The QA role has been modified to be used exclusively for quality acceptance monitoring. The QA staff has been reduced to approximately 10 people with a laboratory to support their testing functions. Two staff members are assigned to perform acceptance field tests and one person is assigned to operate the testing laboratory.

Wasatch uses the QA program to ensure that the quality of the QC tests remains in the acceptable range. A secondary role is to examine the quality of the construction. The QA program is staffed by representatives of the designers, Sverdrup and DeLeuw. They are viewed by the contractor as representatives of the designers.

The quality control program is now responsible for testing, inspection and contractor acceptance. A certified laboratory has been established to support the testing role. There is a staff of approximately 125 people assigned to the QC program. Figure 1 shows the organization chart of the Quality Control program used by Wasatch Constructors. The numbers in the boxes show the number of personnel assigned to each function. A typical segment organization chart is shown in Figure 2. The organization shown is for the Downtown segment and other segments are similar.

Wasatch Constructors indicates that they have sufficient staff to perform the work required. However, they have had some problems in attracting qualified staff to fill all of the positions they originally intended to have. This has been especially true with certified inspectors. They do not feel that this has been a compensation problem but a shortage of certified inspectors available in the job market to fill these positions.

UDOT field personnel have expressed concern with the number and qualifications of the inspectors assigned by Wasatch Constructors to the project. They feel that the field testing forces have been adequate and that the testing phase of the QC program is adequate. They feel that more inspectors are needed to adequately cover the extent of work being performed. They also are concerned that more structural inspectors will be needed as additional bridges are begun.

UDOT and FHWA were concerned about the budget for QC being proposed by Wasatch during the bid stage. They both thought the budget was too low to accomplish the work. The Contractor was asked to review the budget at that time.

Wasatch Constructors indicated that they are more than 90 percent over their budget for QC. They attribute this to an under estimate of the number of inspectors needed in specialty areas such as wick drain and MSE wall construction. They are having to pay higher salaries than expected to attract staff to the project. They are also testing more frequently than they anticipated. This is partially due to the stage construction methods being used. For example, in construction of a bridge abutment normally it requires four tests for compaction for each lift. When constructed in two or three stages the same abutment is tested four times for each stage on the same lift thus resulting in increases in the number of tests conducted.

Wasatch Constructors has recently added a new segment to their organization. The new segment is responsible for surface pavement construction. They have a separate QC group set up to monitor pavements only. This was done because they felt that this work was unique and very production oriented and having a separate segment for this activity would be more efficient.

UDOT Staff and Organization

The UDOT staff organization plan has not changed significantly since the last review was conducted. They continue to operate with centrally located staff used to monitor the overall program and a relatively small staff of six to eight personnel assigned to field offices located in each construction segment. They have a representative from FHWA (a trainee) assigned to each segment and one or two consultant furnished staff with the remainder being UDOT employees. ATSER, a private testing firm, continues to provide verification testing in support of the UDOT Regional Material Laboratory.

UDOT has made several attempts to prepare a manual of procedures for their field people to use to guide them in their role, since it is quite different from the traditional inspection roles. Two drafts have been prepared but neither found to be acceptable so a new version is just being completed and is under review. It is expected that this manual will be completed and adopted later in 1999.

FIELD DESIGN CHANGE PROCESS

Description of the Current Process

Changes to the contract plans can be initiated at two stages:

1. before construction begins or
2. after construction begins.

Changes to the plans before the start of construction are initiated with a Field Design Change (FDC) form. This form, Figure 3, describes the issue and proposed resolution. The approval process remains entirely within the Wasatch organization with notification to the UDOT Design Oversight Engineer. Initially, changes were categorized as either minor or major with the expectation they would be handled differently. Only major changes were referred back to the designers. However, now all pre-construction changes follow this procedure regardless of whether they are minor or major changes.

A different procedure is used after the start of construction. Wasatch Constructors has prepared a detailed procedure for identifying and correcting work that does not meet UDOT standards and criteria. Figure 4 shows a Flow Chart of this process and indicates responsibilities of the UDOT Segment Oversight staff, Wasatch QC and Construction staff and the design engineers.

The primary component of the process is the Nonconformance Report (NCR). A copy of a Nonconformance Report form is shown in Figure 5. An NCR originates and is prepared by Wasatch Quality Control (QC) personnel to identify either work in progress or completed that does not meet UDOT specifications or criteria or Wasatch's design and specifications. The NCR is forwarded to the Wasatch Segment Manager. A copy is also sent to UDOT Oversight for their records. The Wasatch Segment Manager makes a decision as to whether the NCR is an engineering or a construction deficiency.

If the deficiency is related to engineering, it is sent to the design engineers who then prepare a Field Design Memorandum (FDM), Figure 6 shows a copy of this form. Previously, only major field design changes were returned to the designer. This was changed and now all changes are reviewed by the designer. The FDM provides new or revised drawings to correct the deficiency. The FDM is returned to the Segment Manager with a copy sent to UDOT Oversight.

If the deficiency is construction related, the segment production department documents proposed corrective action on the NCR form and returns it to the Segment Manager with a copy sent to UDOT Oversight. The FDM or returned NCR is reviewed by the Segment Manager and UDOT Oversight to determine if it corrects the deficiency. If the proposed action is satisfactory, the Segment Manager issues the FDM or NCR to the construction group for implementation.

If the Segment Manager determines the action does not adequately respond to the problem, it is returned to the appropriate personnel for additional evaluation. If the UDOT Segment Oversight Manager does not agree that the action will result in contract compliance, the two parties will review the NCR documentation. If the Wasatch Segment Manager can demonstrate that the proposed action provides a product that is equal to or better than the standard, a Segment Agreement Memorandum (SAM) is prepared to accept the work. It was estimated that approximately ten percent of the NCRs become a SAM. If the changes affect the cost then a contract change order is processed. The change order impacts the price by either increasing the cost or providing a credit as in traditional contracting.

If the UDOT Segment Oversight Manager does not agree to accept the corrective action, the issue is escalated to the UDOT Construction Oversight Manager and Wasatch Project Manager at the "Hub". If agreement is still not reached it is escalated further up the organizational structure until it reaches the UDOT Executive Director and Wasatch Managing Principal level. If agreement is reached at any level either a SAM, a change order, or other corrective action is taken.

If the corrective action results in work meeting the contract requirements, Wasatch's QC personnel sign off on the NCR and forward it to Quality Acceptance. A copy is also sent to UDOT Oversight who either does or does not concur with the resolution. If UDOT does not concur with the resolution, they issue an Owner's Monitoring Notice (OMN).

UDOT personnel have no authority to issue an NCR. If UDOT personnel identify a work product they believe is not in compliance with the contract requirements they have two options.

They can either discuss the item with Wasatch QC personnel and/or request Wasatch prepare an NCR or they can prepare an Owner's Monitoring Notice (OMN). When UDOT prepares an OMN it is sent to Wasatch QC personnel for review. If UDOT and Wasatch personnel agree on the nonconforming condition, an NCR is prepared by Wasatch and processed. If agreement is not reached and Wasatch QC staff does not prepare an NCR, the item is escalated similar to that described above.

As the Field Design Change process has evolved during the course of the project, the most significant change has been the elimination of the distinction between major and minor field changes.

A minor change was described as one that did not affect other elements or was not related to public safety. Examples of minor changes are revisions to grate elevations on catch basins; locations of pull boxes and adjustment to roadside signs. Previously the designers were not notified of minor field changes.

A major change involved public safety or significantly affected other project elements. Examples of major items include guardrails, catch basin locations, and traffic control elements. All major field changes were sent to the designers.

The current practice is to send all field design changes back to the designer, regardless of whether they are minor or major. This has resulted in some delay in processing of the field design changes.

Tracking the Field Changes

Tracking of all field design changes is the responsibility of Wasatch. Tracking occurs at both the Hub and each segment office, which appears to be a duplication of effort. UDOT oversight staff has access to Wasatch's list of NCRs but doesn't track the status separately.

Quality Control (QC) Testing Program

The contract requires that Wasatch Constructors uses staff and laboratories certified by nationally recognized certification agencies and in conformance with the ISO 9001 certification. Wasatch elected to establish their own laboratory for materials testing for the majority of the work. In order to set up this laboratory they needed to certify the laboratory using the AASHTO certification procedures. They intended to set up the laboratory to provide the majority of the testing capabilities in house with only specialty testing being conducted by outside private laboratories. The process to certify the laboratories was elaborate and very time consuming. It took almost ten months to certify the laboratory in conformance with AASHTO specifications before Wasatch could begin using the laboratory for their own testing needs. To bridge the time frame between the start of construction until certification was obtained Wasatch used a number of private laboratories to conduct tests until their laboratory was certified. In some cases they had UDOT certify the processes and tests, which UDOT was willing to do, until the full AASHTO certification had been obtained. Wasatch now has a certified laboratory, which is assigned to the QC operation operated by Wasatch personnel. It is available on a continuous basis to the production and QC staff for materials testing. The majority of the concrete and earthwork tests are performed in this laboratory. Specialty testing, which requires equipment not provided in the laboratory, is contracted to private, certified laboratories.

Wasatch personnel indicated that the lengthy time required to certify their lab was not adequately anticipated at the beginning of the project. They recommend that any agency requiring such certification allow sufficient time in the schedule to obtain the certifications. It is Wasatch's opinion that certification under AASHTO certification is not possible in a time frame shorter than ten months. On this project they felt that it was worth certifying their own laboratory since the project will last approximately four and a half years but valuable time was lost in the first year while certification was being obtained.

Wasatch performs all field testing through their testing laboratory. UDOT does do some verification testing using both the regional laboratory personnel and a subcontractor, named ATSER. The purpose of these tests is for verification only. Wasatch Constructors are performing the acceptance testing. In addition UDOT is conducting statistical verification of the testing data furnished by Wasatch Constructors. Monthly they prepare statistical reports of all the tests conducted by Wasatch for use in developing trends and verifying that test results are at acceptable levels. ATSER assists UDOT in preparing these statistical verifications. UDOT seems to be satisfied with the use of statistical verification as a means to confirm that quality control testing is performed adequately. They have seen little problems in their verification and have been accepting of the test results.

Quality Assurance (QA) Program For Wasatch Constructors

As was stated earlier in this report Wasatch initially intended the QA role to be one of quality acceptance as well as quality assurance. However, early in the project they determined that it was better to shift the quality acceptance role to the quality control group, therefore a majority of the personnel were transferred into the QC group. Wasatch continues to maintain a QA staff on the project but they are used mainly to check that the design plans are being followed. The personnel assigned in the QA roles on the project are primarily employees of Sverdrup & DeLeuw. Their role has been to provide review of the constructed product for conformance to the design criteria set forth by the designers. The number of staff devoted to the QA role by Wasatch has been minimal with only a small staff available to conduct reviews.

UDOT has, over the course of the last year, begun to discount Wasatch's QA reporting process. They feel that it is not really quality assurance but it is more an oversight that Wasatch is providing to the project from the designers' standpoint. UDOT is satisfied, through their own quality verification process, that the testing is being conducted in accordance with the procedures and therefore the QA reports being provided by Wasatch are not being used currently by UDOT. In fact they feel that this is somewhat a duplication of the effort that UDOT is providing through their own verification testing.

UDOT field staff continues to feel that an independent quality assurance team would be preferable to the contractor providing one. UDOT field staff has not been comfortable with accepting the quality assurance role of the contractor because they do not view it as being independent. On future projects they recommend that the owner consider providing quality assurance either by self performing or independent contracting with an outside party to provide it.

Award Fee

The use of award fee continues to be a problem for both Wasatch and UDOT to administer. UDOT had intended the award fee to serve as an incentive to the contractor to obtain the highest quality product. It was also intended to be an incentive to complete the project on time or ahead of schedule. UDOT has rewritten the procedure twice and has made other minor modifications to the award fee program in an attempt to improve it. The emphasis has been on trying to make it simpler to administer and easier to measure.

Wasatch continues to view the determination of Award Fee as too subjective. They have stated that they were told during the bid preparation that they were to include their contingency and part of their profit in the Award Fee and to assume that they would collect all of it unless they failed to perform. They now feel that it should have been treated as an incentive award. Wasatch considers that an \$18 million portion of the award fee is attributed directly to quality of the project with the balance on incentive for meeting schedule.

To date the contractor has obtained all of the eligible Award Fee on the project except for a small amount withheld in the first payment and another modest amount withheld in the August 1999 payment. The first amount was related to schedule and can still be earned if the contractor meets his proposed accelerated schedule.

UDOT field staff expressed frustration with the Award Fee and how little quality detractors found in the field impacted the overall Award Fee amount. Under the existing program if quality problems are found in the field they are included in a detractor and weighted before used to calculate the Award Fee. The weighting has tended to reduce the impact of these detractors to the point that they did not affect the amount of the Award Fee. The field staff would like to see this change to where significant impact was made by field level detractors. They would prefer to see it used as a pure incentive/disincentive for quality. They also would prefer to have the contractor's role in determining the Award Fee more limited than currently exists. The contractor is provided opportunities to comment on the Award Fee determination and respond to any detractors before any calculations of the fee amount are made.

A more detailed review of the Award Fee program will be conducted under a separate task later this year. The reader is referred to that report for a more detailed discussions of the Award Fee program.

QUALITY

Wasatch's View

Wasatch's view of quality is that their production staff is responsible for achieving quality on the project. The QC staff is there to assist in determining that quality is being achieved. If quality is found to be suffering then production is to make the changes necessary to correct the problems. The Wasatch QC management staff indicated that they have always had total support for this philosophy from Wasatch's production and management level staff.

Wasatch QC staff is a bit frustrated with the extent of the testing level that UDOT has insisted on. They feel that the frequency and number of tests is excessive for many of the work items.

They have indicated that more than 90 percent of the tests are conforming at the time of the first test. Less than 10 percent of tests are made to monitor re-worked items.

Wasatch has experienced some minor quality problems, mostly with local concrete suppliers furnishing concrete on bridges. They cited a couple of examples where portions of bridge decks had to be removed and replaced due to the concrete not meeting specifications. They have also had some problems with pre-cast concrete beams not meeting specifications and requiring replacement after delivery to the site. They indicated that they were able to remove and replace the poor materials fairly easily because they had good records of where the materials had been placed and the source.

Wasatch's staff attributed these problems to poor quality control by their subcontractors, mostly suppliers. They have stationed their own quality control personnel at some of their subcontractor's facilities to monitor the products being produced. They feel that the quality problems could have been remedied if their subcontractors had instituted the same level of quality control measures at their plants as Wasatch has on their self-performed portions.

UDOT's View

Interviews with UDOT staff were conducted to obtain an assessment of the level of quality being achieved. The following list identifies the majority opinions (in some cases the unanimous opinion) of the individuals interviewed:

- The QA staff is not independent from Wasatch Constructors creating a potential conflict of interest.
- There is insufficient inspection staff assigned to the project to adequately monitor the work. Nighttime work is particularly affected.
- They are comfortable with the level and quality of testing that is being provided.
- UDOT staff would prefer to have more authority over quality acceptance.
- The overall quality of the work was rated as average and meets the minimum level acceptable by UDOT.
- The quality of materials, especially earthwork and gravels, has been very good with only minor, insignificant exceptions.

Long term maintenance and how that is intended to affect quality

The contract for the Design/Build project allows UDOT to exercise a clause to have the Contractor perform maintenance, at a predetermined price, on the completed work for a period of five years, with options for up to five additional years in one-year increments.

This clause was intended to provide the Contractor an incentive to perform high quality work. If the quality is below average and UDOT invokes the maintenance clause, the Contractor could be responsible for significant maintenance costs.

The Contractor would be responsible for such items as repairing or replacing cracked pavement, excessive roadway settlement, excessive retaining wall or bridge deflections and bridge deck cracking. The clause is not intended to include routine maintenance items such as snow removal, landscape maintenance or post accident repairs.

UDOT has until six months prior to the target completion date to inform the Contractor whether or not they intend to exercise the clause.

LESSONS LEARNED

Field Review Process

Wasatch Constructors has instituted a field review process that basically sends all field design changes back to the designer of record for comment prior to implementing them in the field. It appears that it would be more efficient if Wasatch had delegated this responsibility to a field level resident engineering position with each segment having a resident engineer on staff who could represent the designer in making field decisions. Many of the decisions could be made at the field level without having to go back through extensive design review. This would speed up the process.

Laboratory Certification

Wasatch Constructors underestimated the time required to certify their materials laboratory for the project. They indicated that it has taken approximately one year to certify their laboratory. On future projects the owner and contractor should allow this much time before their own laboratories could be certified.

Personnel Certification

Wasatch Constructors has had some difficulty in attracting certified inspection personnel to the project. This has been due primarily to a shortage of qualified/certified personnel in the local market area and to some degree nationwide. They have had to perform their own training to certify their own inspectors in some cases.

Quality Assurance Role

UDOT field staff has stressed that they prefer to retain the quality assurance role.

Award Fee

Neither Wasatch Constructors nor UDOT has been pleased with the Award Fee program. It has been more time consuming than expected to administer and calculate. Many on both sides have suggested a less subjective process would have been preferable, perhaps one tied more closely to milestone. This program will be evaluated in a separate evaluation later this year. The reader is referred to that report for a more complete discussion of the program and recommended improvements.

Field Procedures Manual

The Owner has had to develop their own manual of operation to maintain consistency in the oversight role. This is a new role for the owner and prior procedure manuals could not be used on this project. The owner has had some difficulty in developing these manuals to reflect what is occurring in the field and what procedures they want to follow. It will be almost two years after the start up of the project before the owner actually has their own operations manual in place. This is an area where UDOT could have developed a manual earlier in the schedule, before construction began.

Magnitude of QC Program

Wasatch Constructors has indicated that they are running considerably over budget for the quality control program. They attribute most of the problems with the budget to under estimating the amount of testing and inspecting that is required. It has been further complicated by the staged construction that has been used to expedite the project. In the future, contractors should evaluate the process that they intend to use to construct the project in more detail and take this into account as they establish budgets for providing these services.

CHAPTER 3

Innovative Construction Methods - I-15 Design/Build Project

The purpose of this report is to document the “innovative” construction means and methods employed by Wasatch Constructors on the I-15 Design/Build Project. While most of the methods described are not new to other states and jurisdictions their use by UDOT on a project within this state was new. In some cases the extensive use of these methods was unusual. This paper will describe briefly the methods used and how successful their use has been to this stage of the project (60% complete).

UDOT is conducting separate detailed studies of some of these methods and intends to publish the results of these more detailed investigations when they are completed. Those topics include use of wick drains, geofam, two-stage walls and mechanically stabilized embankment (MSE) walls. But since completion of some studies may not occur for several more years it was felt important to present a brief discussion on those features in this paper to alert interested parties of the more detailed studies underway.

FLEXIBILITY IN FOUNDATION TREATMENTS

One of the challenging aspects of this project is the presence of very soft foundation soils under much of the highway. The Salt Lake Valley is a remnant of ancient Lake Bonneville. The foundation soils contain layers of very soft, compressible clay and silt with sand lenses of varying thickness interspersed. The farther north the location in the valley the softer the foundation soils tend to be. Furthermore, the soils are highly compressible resulting in significant settlement when loaded with structures and fills.

When the original features of I-15 were constructed in the 1950's and 1960's most foundations were surcharged for several years prior to constructing the final pavement and structures to allow the foundations to consolidate adequately. With a four and one-half year time limit for reconstruction of I-15 there was not enough time to construct the features in the manner normally used in the Salt Lake Valley. The required use of Portland cement concrete pavement (PCCP) as the final roadway surface made excessive settlements, after fills were placed, unacceptable. Furthermore, all bridge abutments were required to be placed on pile foundations, a typical Salt Lake Valley area requirement. Therefore, innovative ways to construct on soft foundations were considered by UDOT as necessary to complete the reconstruction.

Several options were included in the performance specifications developed by UDOT. These included use of wick drains to accelerate consolidation under load, mechanically stabilized embankment retaining walls (MSE) used to accommodate considerable amounts of settlement, light weight fill and Geofam fills, lime cement columns, stone columns and other options to account for the settlement amounts expected. It was projected that settlement on some of the highest fills could approach two meters.

Secondary settlement, the settlement that occurs after pavement is placed, is limited by the contract to less than 10 cm. If more settlement occurs then the Contractor, under terms of the performance specifications and optional long-term maintenance agreements, is responsible to repair or replace it. The objective of the designers and contractor was to construct fills so that all consolidation and settlement would occur during construction. This typically allowed a

maximum of about eighteen months for settlement and consolidation to occur prior to placing pavement or bridge decks.

Lime Cement columns were considered one option. These consisted of augering or boring holes into the native soils and as the auger is withdrawn a lime cement compound is injected into the soils and mixed to increase the strength. Several patented process are commercially available for this technique. It does require specialized equipment to construct.

Stone columns were also considered. This process is similar to a lime cement column except the material removed from the borings is replaced with small stones to provide increase bearing capacity. Pea-sized gravel is typically used as the “stone”.

Wick drains were considered by UDOT as required for much of the softer foundation areas. The wick drain process consists of driving a corrugated plastic wick wrapped with a geotextile filter fabric into the ground. The wick drains provide a relief avenue for water compressed out of the soils as consolidation and settlement develops in the deeper soils. Properly placed the drains can accelerate the rate of settlement and consolidation and reduce the time required to obtain the required settlement. Drains were typically advanced into the foundation soils by pushing or augering them into place. Most of the drains on I-15 were placed by pushing them into the foundation soils up to 40 meters in depth using specialized equipment. The length and spacing of wick drains was carefully planned to achieve the desired settlement amount. Many drains were placed as close as one (1) meter on center under embankments. A layer of free draining granular filter material was placed on the surface of the wick drains extending outside of the embankment area to provide continuous draining.

Geofoam is a high density expanded polystyrene material formed into large blocks. It is very light weight and was used in place of granular fill in embankments. Because it is about 1/10th the weight of granular fill, using it reduces the settlement amounts that are induced with construction of fills and embankments.

An alternative to the Geofoam was the use of lightweight granular fill materials in place of imported granular borrow. Two types of lightweight fill have been used on I-15. Scoria, a naturally occurring volcanic material, and slag from steel mills have been used. Each of these materials has a lighter unit weight than granular borrow but each is heavier than the Geofoam material. Geofoam is more expensive than the other options. The decision to use Geofoam has often been made after the contractor made an economic comparison of the higher costs versus lighter weight and lower settlement potential was made.

DESIGN LIFE/PERFORMANCE LIFE

Pavement Performance Life

For the I-15 project, UDOT used a performance specification which required a pavement design life of 40 Years for all mainline pavements including, ramps, collector-distributor (C-D) roadways, auxiliary lanes, and intersecting roadways at interchanges. Specific concerns addressed in the specification resulted from the poor subsurface soil conditions existing throughout the corridor and discussed elsewhere in this report. Because of these poor soil conditions concerns for frost susceptibility and entrapment of water within the roadway prism governed some of the decision-making process.

Two parameters that are important in any pavement design are the projected traffic loading and the underlying soil support. Based upon the values from these two parameters, a typical design-life for a rigid concrete pavement is 30 years on I-15. UDOT increased it to 40-year design life based upon a projected pavement loading of 90 million EASL's. UDOT also specified that the roadway shoulders were to have the same pavement structural section as the roadway pavement.

To address the concern for the expected poor underlying soil support, an open graded base course was specified with underdrain or edge-drain systems to remove moisture from the top 36" of base and subbase materials, increasing the soil support values and decreasing the frost potential. Although the open graded material was by nature difficult to compact, indications are that the placement has been successful.

Other innovations were:

- Use of perpendicular random and staggered joints within the PCCP to mitigate the development of harmonic vibrations within vehicles traversing the surface
- Use of load transfer joints to spread vehicle loads over a larger percentage of surface area,
- Use of "engineered" bumps in the pavements prior to the approach slabs. The engineered bumps were an attempt to anticipate the settlement of an approach slab, so that once the slab settled the expected amount, the approach slab edge would align vertically with the adjacent pavement surface.
- Limit joint spacing to 4.5 meters.

Ride quality was another innovation for this project. A maximum of 1000 mm/km (1/8" in 10') deviation was specified over the first 4 years of surface life and 1400 mm/km (3/16" in 10') after 9 years. These maximums are greater than the typical smoothness specifications used by most DOT's and UDOT prior to the I-15 project.

Structure Performance Life

A 75-year structure life was specified for all bridge structures designed within the I-15 project. This specification was in addition to the seismic criteria discussed elsewhere within this report.

The innovations used were:

- Use of epoxy-coated conventional reinforcing (Prestressing is not coated)
- Minimizing the use of deck joints
- Disallowance of steel decking materials due to propensity for corrosion
- Use of deck coatings (stain) to seal against water and salt seepage through cracks in the concrete surfaces
- Bridges 110 m or less in length will have no joints and will use integral abutments
- Use of transverse post-tensioning on decks (new to Utah)
- Provision in specifications that required the contractor to provide a 75-year life cycle cost analysis as a part of bridge design and analysis, including costs for scheduled maintenance and repair.

MSE WALLS

A number of I-15 construction site conditions exist which resulted in the choice of mechanically stabilized embankment (MSE) walls for this project. Some of these conditions included right-of-way limitations, surcharging requirements, extensive settlement potential, and an accelerated construction schedule for the design/build project.

The I-15 corridor is a heavily used urban freeway system that traverses commercial, industrial and residential properties. Extending right-of-way to accommodate a wider section would have been an expensive and time consuming undertaking. Retaining walls of some sort were required to contain the widened roadway section within the existing UDOT property limits.

The deep clay sediments in the Salt Lake valley exhibit excessive consolidation and settlement displacement under loads. Much of the consolidation can be forced by initially overloading the area with layers of fill materials that are subsequently removed for final construction. Heavy surcharging can be a great aid in meeting accelerated construction schedules. However, if more traditional retaining walls had been constructed it would have necessitated removing most of the surcharge embankment and constructing the walls from the foundation level upward. The Contractor used MSE walls because they are flexible and can be constructed in stages. Because the MSE wall is “flexible” it can tolerate significant settlement without needing to be reconstructed. In areas where very high settlement was projected to occur a two-stage wall was constructed. In other areas a single stage wall was constructed.

Two kinds of MSE walls were used on the I-15 project. The single stage wall is constructed at one time and consists of a reinforced earth embankment with a pre-cast concrete facing panel constructed contiguously. The other type of MSE is called a two-stage wall. The first stage consists of the reinforced embankment construction and the second stage consists of the placement of the finished wall panels after the embankment has settled.

A description of the two-stage wall system construction sequencing follows:

1. The site is prepared for embankment.
2. A layer of geotextile material is laid on the embankment area.
3. Embankment fill is placed and compacted to a compacted depth of approximately 762mm.
4. A geotextile material, which projects beyond the sides of the fill, is wrapped over the top of the next fill lift.
5. Metal tie straps consisting of a wire mesh mat are laid on top of the fill perpendicular to the edge of the embankment. Length, thickness and spacing of the mats are determined by design requirements such as fill height panels and geometry.
6. The next layer of geotextile is placed and the previous steps are repeated until the embankment reaches the desired height. The height consists of the design height of the embankment plus the height of the desired surcharge fill.
7. After a suitable time has passed to allow settlement of the native foundation soils to occur, the surcharge material is removed.

Photo 1 Two-staged Wall



8. A face mesh of W11xW11 welded wire fabric (WWF) is placed on the outer face of the embankment and connected to the wire mats embedded in the fill.
9. Fittings consisting of coil inserts are attached to the embedded mat ties at a spacing to match the pattern of similar coil inserts that are attached to the precast wall panels.
10. A small 152mm by 305mm concrete leveling pad is constructed on the alignment of the face wall.
11. The wall panels are then placed on the footing pad and connected to the fill using turnbuckle threaded coil inserts and rods and tightened to adjust the vertical wall alignment.
12. The void between the embankment and the wall panels is filled to a depth of 1.5 meters with lean concrete to stabilize the lower portion of the wall.
13. After the roadway and barrier are constructed, a concrete cap is placed between the back of the barrier extending over the top of the wall panels to seal the void between the soil embankment and the concrete face panels.

Figure 1 shows a typical two-staged wall detail. Photo 1 shows a picture of a typical installation.

convenient way of attaching parapets, sound walls, crash barriers or other types of appurtenances directly to the walls. The moment slab was used as a way to overcome this problem. The moment slab is not a new concept and has been used elsewhere with wall designs by VSL, Retained Earth, Hilfiker and others. VSL provided the design of the MSE walls for this project.

Roadway barriers must be designed to withstand substantial horizontal impact loads. Since a two-staged MSE wall is not capable of withstanding a moment at its top induced by an impact on a barrier, the barrier was designed to attach to its own foundation. In this case, the barriers were placed on a reinforced concrete moment slab that varied from 2.4 to 5.2 meters in width. Slab thickness was typically 330 mm. The taller impact barriers used on this project can induce higher moments at their base than shorter ones typically used. The barrier reinforcing was designed to withstand the impact loads and the slab was reinforced to withstand them.

The width and thickness of the slab was designed to provide a dead load resistance to the overturning moment. Also aiding the overturning moment resistance is the weight of the impacting vehicle on the slab and the longitudinal load distribution. The typical applications where moment slabs were used is shown in Figure 2.

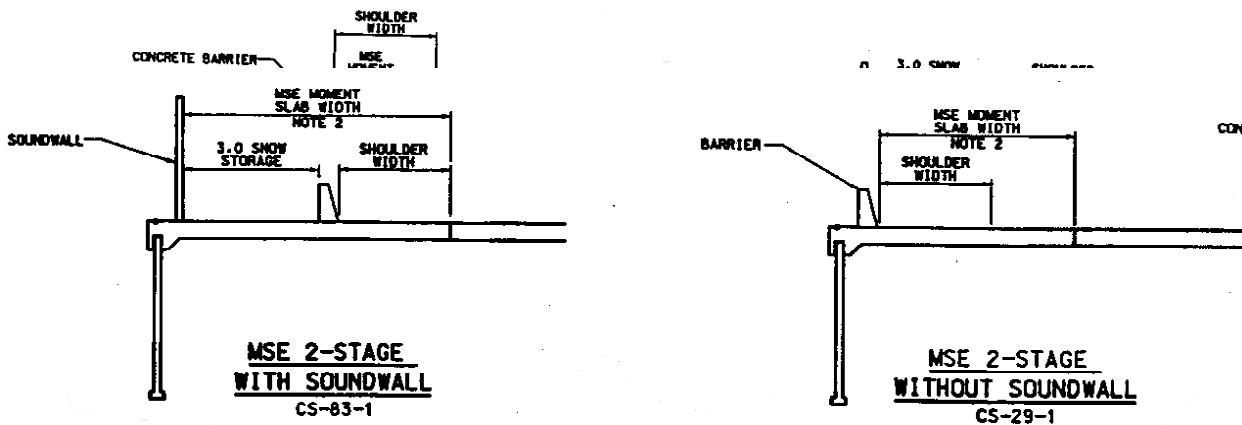


Figure 2 Moment Slab Examples

Figure 2 Moment Slab Applications

The design as presented in the I-15 project plans included drilled caissons placed at the roadway edge of the slab. The purpose of these piles was to increase the uplift resistance and provide resistance to sliding. Both Contractor and UDOT personnel indicated that no drilled caissons have actually been installed in conjunction with moment slab construction to date. The dead load weight, soil friction, and distribution of point loads in slabs has been considered sufficient to overcome the sliding and overturning forces without the piles.

Figure 3 shows details of how this was designed.

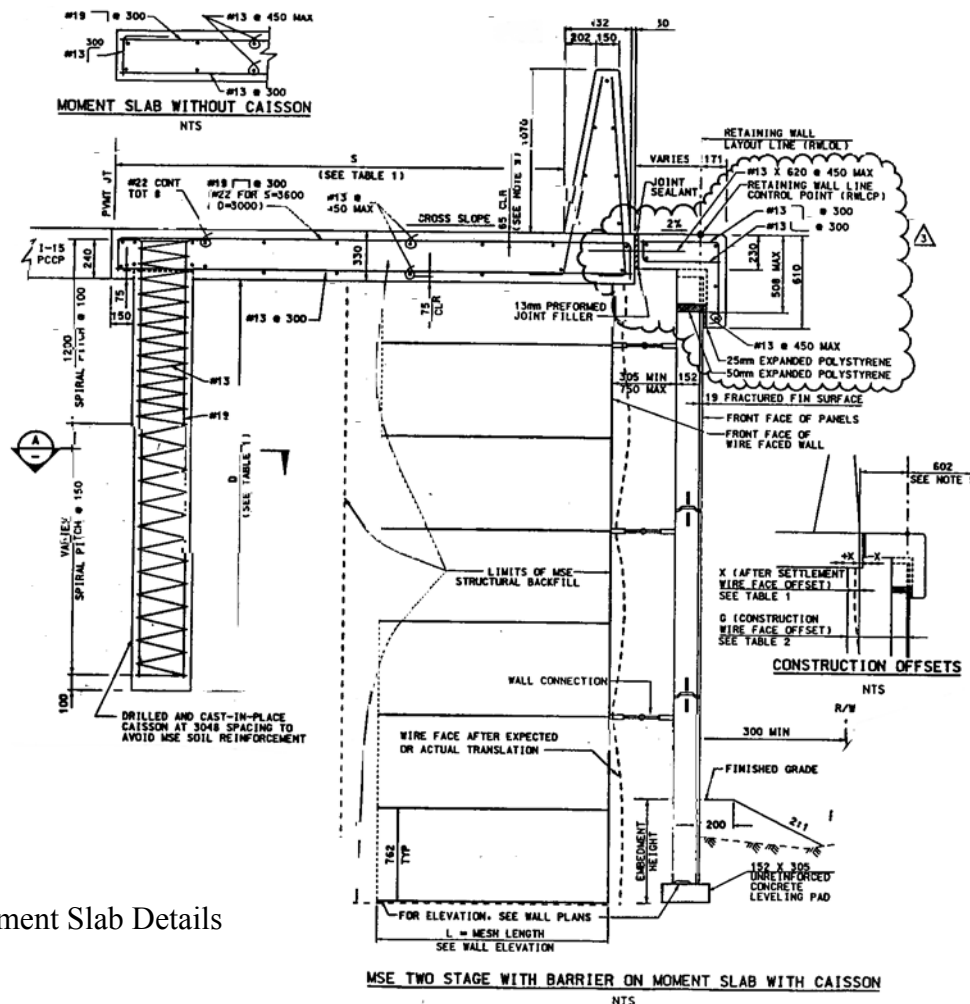


Figure 3 Moment Slab Details

The typical installation places the back face of the barrier 500-mm or more inside the outer face of the MSE wall panels. An “L” shaped cap is then placed on top of the wall and attached by reinforcing to the moment slab. Figure 4 shows this detail. This cap ties the wall and slab together and provides a barrier to prevent infiltration of water into the soil behind the wall panels.

The contractor field personnel indicated preference for more options but have successfully used these details in the construction. Moment slabs have been used most frequently in areas where Geofoam fills and 2-stage MSE walls were constructed.

To date this has proven to be an acceptable solution given the time available for construction even though contractor personnel would have preferred to have alternate solutions from which to

choose for a given application. They made the decision to use this solution due to time constraints.

JUMBO SLABS

Construction conditions in the Salt Lake Valley include deep compressible soils throughout the area. Installation of structural foundations and roadway fills of any magnitude can cause subsidence with subsequent differential settlements that can result in damage to road and bridge structures. Generally the differential settlement manifests itself as a vertical miss-alignment between the roadway surface pavement and the bridge deck surface at the bridge abutment. This miss-alignment is not only irritating to the vehicle driver but it also causes excessive impact loads to the structure.

Subsidence of fill at the abutment of a bridge can be caused by compression of the native soil under the fill or consolidation of the roadway embankment due to inadequate compaction during backfilling work. Bridge abutments are typically founded on pile foundations that tend to settle less than earth fills.

Approach slabs offer a transition between the roadway pavement section and the bridge deck at the abutment. Normally the slab is cast on grade and rests on a ledge at the backwall of the abutment. The theory behind this design is that the slab will span between the end of the roadway pavement and the bridge. After a period of time a void can develop under the approach slab due to fill settlement. The slab must therefore be designed to support the traffic loads with a void beneath the slab.

The I-15 project uses a rigid pavement design and also has numerous deep fills. With the possibility of substantial settlement, longer and thicker approach slabs were considered necessary. Longer slabs were also considered to be required to reduce the abruptness of the vertical angle change at the bridge.

Approach slabs have been designed in the past with a thickness of 254 to 305 mm. On this project four slabs, Type A, B, C, and D, were designed. Lengths of slabs vary from 8 meters to more than 16 meters. The shorter slabs are 375 mm thick and the longer slabs are 580 mm thick. Because of the increased thickness of the slab they have become known as “Jumbo” slabs. The four types not only provide two different thickness but also provide different joint treatments at the bridge. According to UDOT personnel, the thickest slab has only been used in one location.

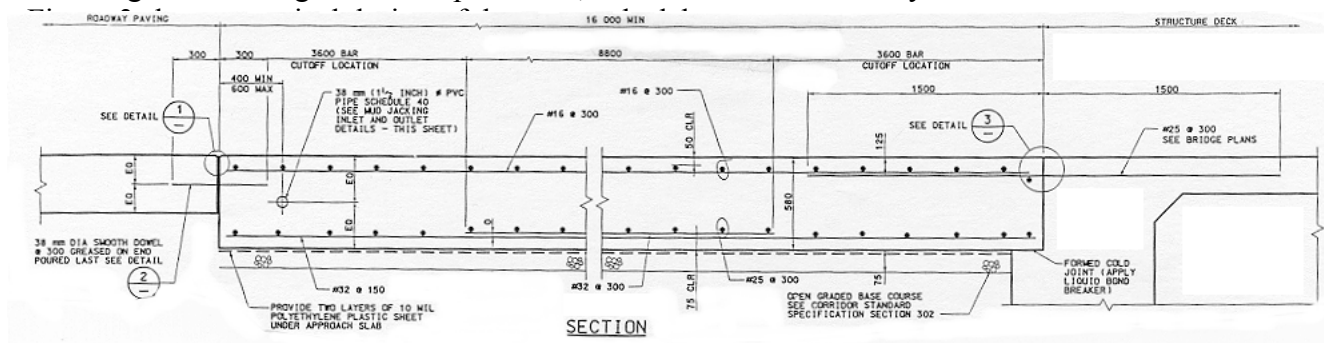


Figure 4 Typical Approach Slab

Another innovative feature of the “jumbo” slabs is the installation during construction of a system of 38 mm diameter pipes within the slab to provide for future jacking of the slab, in the event excessive settlement occurs. The intent is to provide the plumbing to permit injection of concrete or other substance to raise the outside end of the slabs. Figure 5 shows typical details of this connection and piping. To date none of the slabs has required jacking.

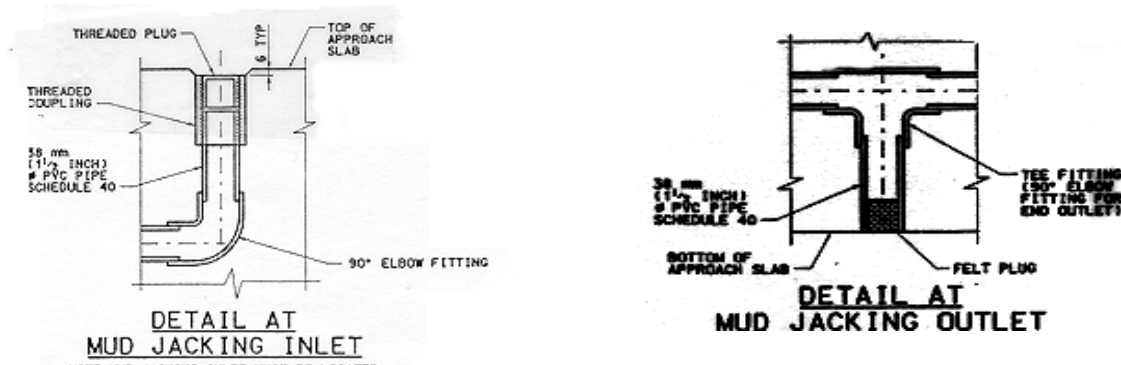


Figure 5 Mud Jack Details

NEBRASKA GIRDERS

Wasatch Constructors has used a pre-cast, pre-stressed concrete girder called a modified Nebraska Girder on structures where pre-cast girders were used. They also decided to use spliced girders to achieve longer girder spans. This is being used primarily at the location of the single point urban interchanges. The design is similar to a girder used by the Nebraska Department of Transportation but has been modified with an enlarged bulb at the base. The stated reason for using this girder type are that they are:

- lighter than an AASHTO type girder
- capable of longer spans than ASSHTO girders
- have been used by the Contractor on other projects so their crews were familiar with their use.
- permit wider girder spacing resulting in fewer girders in spans. The weight reduction is in the range of 500 kg per linear meter of girder.

In spliced girder applications, three girder sections are spliced together to form the span. Girders are tied together and post-tensioned with the splices cast in place. Post tensioning tubes are cast into the beams when fabricated. Figure 6 shows typical cross sections of the beams used. Girders were manufactured by a local subcontractor. They set up a special operation to manufacture them for this project.

There have been reports of quality control problems with the girders. Some of the first group of girders supplied to the project had vertical cracks visible in the web section that raised concerns among the UDOT oversight personnel. A panel of experts was assembled to evaluate the potential problems and to develop procedures to limit future problems. Based upon the recommendations of the panel, and concurrence by UDOT and FHWA, some of the girders were replaced and the manufacturing process modified to reduce the potential for cracking of the webs. One potential problem identified was with the method used to release pre-stressing cables that resulted in cracking of the beams. This method has been modified with satisfactory results.

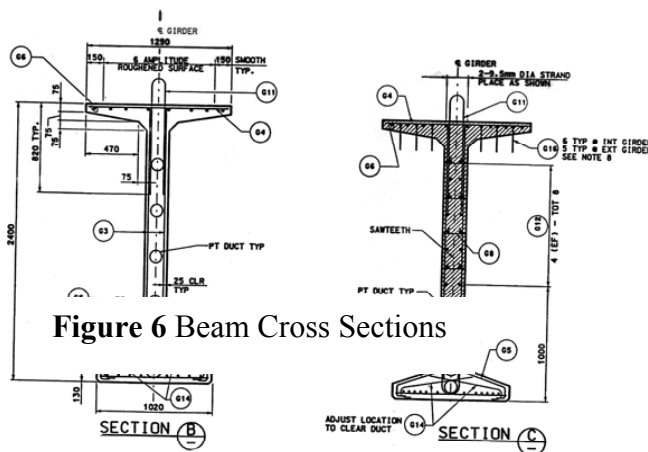


Figure 6 Beam Cross Sections

Another problem observed by UDOT had been the fragility of the girders. Because they are relatively deep girders with thin flanges and bulb corners they tend to chip and crack if not carefully handled. UDOT is more used to an AASHTO type girder which has a more robust cross section without thin edges. UDOT has been concerned that many girders have required patching and often time's replacement because of the damage that has occurred while handling and placing the girders. They have been supportive of the use of the girder type but have been

concerned about the need to handle the girders in a more careful manner than the contractor was use to doing. Once the girders are in place and decks cast UDOT has generally been pleased with their use.

The Contractor continues to use this type of girder because he feels that it presents a significant cost savings over other types of girders.

GEOFOAM FILLS

The Contractor proposed several methods to accelerate the placement and settlement of embankment fills used on the project. The schedule for construction required solutions to manage the settlement and minimize it where possible. One option used has been to replace granular borrow and fill with lighter weight materials to reduce the resultant embankment and foundation settlement. Scoria, a naturally occurring expanded shale material, slag and polystyrene foam (Geofoam) have all been employed to reduce the unit weight of the fill used.

Scoria and slag have been used in many other projects in Utah in the past but extensive use of Geofoam has not occurred previously on a UDOT project. A local manufacturer of foam developed a foam product to be used in a geotechnical application they called Geofoam. The foam weighs approximately one-tenth as much as the equivalent depth of the granular fill it replaces.

The Contractor has used Geofoam in two types of applications.

1. Where settlement of the foundation areas would pose potential problems with existing utility lines not scheduled for relocation.
2. Where the construction schedule did not permit sufficient time needed for embankment settlement before construction of pavement or structures.

At several locations on the project, utility lines are located very near the proposed embankments or cross under the embankment. The most significant types of utilities that could be potentially affected by excessive settlement were gravity pipelines, such as sanitary and storm water sewer lines. There were also other types of utilities where extensive settlement was expected to result in unacceptable conditions or expensive relocations. In these areas the Contractor used Geofoam as a significant part of the fill to reduce the loads and associated settlement. Most of this

application was located in the Downtown segment of the project where foundation soils are very soft.

At several locations the Contractor needed to complete his work quickly to permit switchover of traffic to new lanes before the end of 1999. This was particularly necessary near the 600 South off ramps that needed to be completed in 1999 to maintain traffic into Downtown Salt Lake City via the Downtown interchanges. Therefore sufficient time for new embankment to settle was not possible and still implement the traffic management plan require to meet the construction schedule.

The Contractor, has been using large blocks of Geofoam in the construction of the embankments. The foam is an expanded polystyrene foam fabricated in solid blocks. The block dimensions are approximately 1.2 meters square by 6 meters long. The blocks are stacked much like hay bales using metal connectors to keep the blocks in place during construction. The metal connectors are placed at joints and spiked into the blocks on each side to hold the blocks firmly together. Once the blocks are placed, a geo-textile fabric material is placed on top of the blocks, encapsulating them. A reinforced concrete load distribution slab is then placed on top of the geo-textile fabric. This slab is reinforced with epoxy coated reinforcement steel and is generally 16 mm thick. After the concrete has been placed at least one meter of granular fill material is used to completely encapsulate the foam blocks. After the fill is in place the standard section for pavement or abutments is used.

This procedure was developed to meet design criteria considered by the design team. They were concerned about protection of the foam, which is susceptible to damage by exposure to sunlight or through contact with petrochemical compounds that can degrade the foam. The designers also wanted to distribute the imposed loads over more of the area of the foam blocks and the concrete slab is intended to provide this distribution. Figure 7 shows details of the construction method used. Photo 2 shows a Geofoam wall, load distribution slab, granular fill and Jumbo slab used at an abutment of one of the structures located at 800 South and I-15.

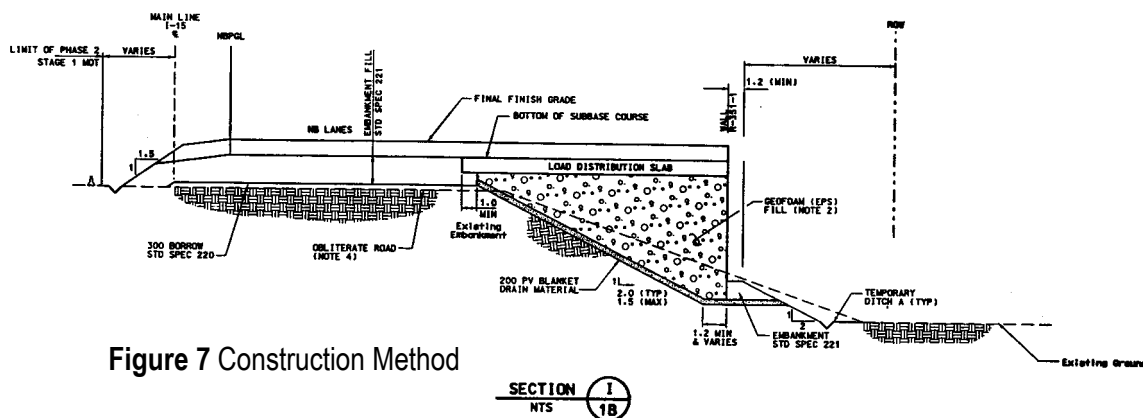


Figure 7 Construction Method



Photo 2 Geofoam Wall Detail

Generally the performance of the Geofoam has been as expected by the Contractor and UDOT. Several fills ten (10) meters or more in height have been constructed. The only unexpected observation has been that settlement within the Geofoam block structure has been greater than expected by either UDOT or Wasatch. Neither expected any significant settlement to occur within the block units but measurements have indicated several millimeters of settlement at some locations. UDOT is conducting a more extensive study to evaluate Geofoam applications on this project. It is

expected that results of these reports will not be available for two more years. The reader is referred to UDOT for status of these reports.

One significant event occurred during construction that is noteworthy. During construction of a segment near 500 North, which used Geofoam as a fill substitute, a crane came into contact with an overhead power line. The resultant fire was hot enough to destroy the crane and cause severe damage to the concrete pavement section on which the crane was parked resulted. The Contractor removed the pavement and uncovered the Geofoam fill section to inspect for any damage to the Geofoam sections. No damage was apparent to the Geofoam blocks. The only damage visible was to the outside edge of the Geofoam section where the reinforcing steel used in the load-distribution slab had electrically grounded. The damage to the foam was not considered significant and the foam was not replaced as part of the repairs. Fuel that spilled from the crane also did not damage the foam. UDOT was pleased with the performance of the Geofoam fill under this situation.

LIME CEMENT COLUMNS

Lime Cement columns (LC columns) have seen only limited use in the United States, but have been used successfully in Scandinavia and Northern European countries for more than 25 years. They are primarily used for settlement reduction and bearing capacity improvement for soft, clayey soils and to improve the shear strength and stability of embankment foundations. The LC column is constructed using a crawler mounted machine that can be computer controlled. An LC column is constructed by injecting, under air pressure, a combination of dry (unslaked) quicklime and cement into soil, and mixing the soil, lime, and cement with a Kelly-bar-mounted tool as it is rotated and raised to the surface creating a column of treated soil. The treated soil hydrates using water from the surrounding soils with a resulting rapid increase in soil-column strength. The strength continues to increase for approximately one year at a diminishing rate.

In their original bid proposal to the I-15 project team, Wasatch Constructors listed LC columns as a potential technology for settlement reduction and soil stabilization. Some of the reasons cited by the Wasatch team for selection of LC columns in preference to other accepted methods of soil stabilization were:

1. LC columns were expected to be stiffer than stone columns and lead to reductions in settlement.
2. LC columns were expected to be more effective in reduction of secondary settlements.

3. LC columns were less permeable than stone columns, thereby reducing water flows through the soils where groundwater is encountered.
4. LC columns were anticipated to be quicker to install and less expensive than other technologies such as stone columns and deep soil mixing.

However, due to their relatively high installation cost and concerns about subcontractor production rates, LC columns were installed at only one (1) location (Wall SS-01) on Segment 1. This wall is on the I-80 spur of I-15, located on westbound I-80 at the intersection of 300 West, and was constructed as a single-stage MSE wall. This wall is approximately 15 meters tall (maximum) and is designed for a 3 meters surcharge. Concerns about a potential stability failure of foundations on adjacent commercial property motivated their use.

Other techniques such as geotextile reinforced slopes, stability berms, and multi-stage MSE wall construction were not feasible due to right of way constraints and aggressive construction scheduling. The primary difficulty noted in the installation of LC columns was due to the presence of cobbles in the site soils causing lower production rates. Additionally, the quantity of LC columns actually required to achieve the degree of soil stabilization necessary increased approximately 4 to 5 times over the original estimate.

UDOT has installed instrumentation near wall SS-01 to determine the total settlement and differential construction settlement in the LC column stabilized soils during embankment loading. The differences in load transfer characteristics between treated areas and untreated areas, rate of settlement, and total settlement will also be monitored.

STONE COLUMNS

Soil liquefaction is typically associated with saturated loose sands and silts that contain very low amounts of cohesive material. The sands in general have large void ratios and tend to compact during strong ground motions. If water cannot drain rapidly, pore pressures will increase to a level that equals the overburden pressure. At this point, the effective stress between the soil particles is essentially zero and the soil mass liquefies. Soils with large amounts of cohesive components (clays) are not generally as susceptible to liquefaction because they exhibit shear strength at zero effective stress.

Stone columns have proven effective in reducing hazards from the two primary sources of liquefaction-induced ground failure, lateral spreading, and loss of bearing capacity.

The stone column system chosen by Wasatch Constructors for the I-15 Reconstruction Project was a system recommended by Hayward-Baker, Inc. This system was preferred due to its estimated lower installation cost and higher production rate than other typical treatments for foundation support on soft soil sites such as deep piles, over-excavation and replacement filling, or soil mixing.

The stone column system consists of an augered pier cavity into which graded aggregates are compacted in lifts approximately 300 mm thick. The aggregates are compacted using ramming equipment that imposes lateral pre-stress into the undisturbed soils surrounding the column. This increase in lateral or horizontal stress in the surrounding soils must first be overcome by strong ground motion induced stresses before liquefaction will occur. Additionally, for liquefaction

mitigation, free draining material can be used so that the stone column acts as a drain to relieve excess pore water pressures.

Stone columns were used in three locations on the project, one location in Segment 2 and two locations in Segment 3, and reportedly were easily installed. Additional locations for remediation were recommended by the project geotechnical engineers but were not implemented since the post-earthquake safety factor of 1.1 (UDOT Criteria) was exceeded for the location. Long term settlement performance for these columns was specified as less than 3" in 10 years. The QA/QC system implemented by UDOT and Wasatch Constructors was modified due to initial difficulty in monitoring the installation of the stone columns.

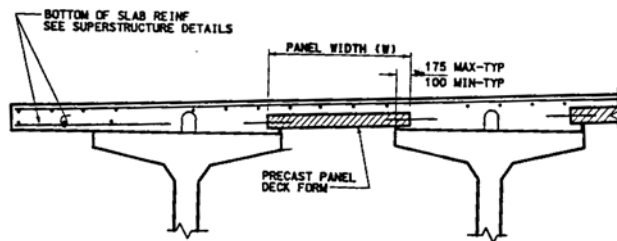
PRE-CAST, STAY-IN-PLACE DECK FORMS

The designers specified pre-cast, stay-in-place concrete deck forms for most of the bridges. These are typically 4 inch thick pre-tensioned concrete slabs which can be produced offsite and erected on either steel girders or pre-stressed concrete girders. They are used on all concrete girder bridges and some of the steel girder bridges. However, some panels are constructed without the pre-stressing. These stay-in-place forms are used by several other states, the most notable being Texas. Wasatch Constructor's management is enthused about them because they save time and labor normally required in forming a deck soffit and removing the forms after the deck is placed. The pre-cast panels are set on the girders and become an integral part of the deck. They indicated that the potential labor savings was significant due to limited available workers who were experienced in concrete deck construction.

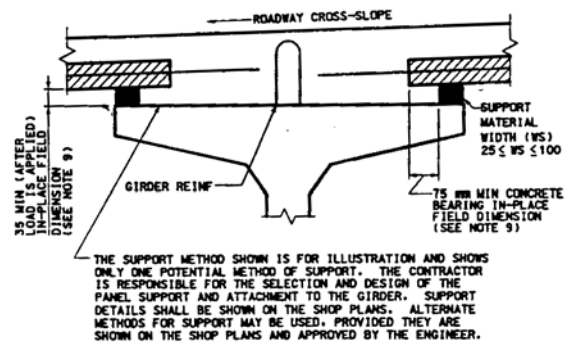
The support for deck panels expressed by the UDOT field managers vary between the three segments. On the north segment they have observed significant cracks within the first twelve months after placing the panels. They also expressed concern that cracking could occur at the interface between the panels and the top half of the deck, which is cast in place over the panels. Another concern was that the un-coated prestressing strands used in the pre-stressed panels could corrode over time.

In the center segment UDOT observed similar cracking. They also became concerned that the lack of sufficient roughness of the top finish of the panels could result in inadequate bond with the cast-in-place deck concrete. The specifications require 3-millimeter deep grooves but do not stipulate a spacing dimension. The grooves may also be too far apart. UDOT is concerned that the lack of adequate roughness will result in inadequate bonding between the panels and cast-in-place concrete.

In the beginning UDOT field personnel observed problems setting the panels because the tops of the concrete girders were uneven. They also observed problems with camber control of the girders. The Contractor resolved this by using a variable thickness styrofoam block on the top of the girder flange to level the panels. A blocking strip was cut to match the desired deck camber. It also served to help resolve the seating problem on the uneven girder tops. Figure 8 show details of the panels and supports used in the construction.



SECTION
Figure 8 Panel & Support Detail



SUPPORT DETAIL

Interestingly, the south segment UDOT personnel did not observe these same problems with the pre-cast deck panels. They have not observed any cracking. This may be due to the fact that a different contractor is building the bridges on this segment. The UDOT Segment Manager said that the panels worked well for constructability. He did express some concern about long term maintenance should any problems develop. The UDOT project Technical Manager felt that the excessive cracking found in other segments may be due to releasing the pre-tensioning strands too soon. The Contractor has made several revisions to the fabrication process of the panels that has reduced the observed problems in all segments.

Overall, it appears that most UDOT personnel and the Contractor like the pre-cast deck panels because of the shorter construction time required. The problems encountered have been attributed to inadequate quality control, which have been resolved.

SEISMIC DESIGN

Seismic design was a major concern during project planning because of the proximity to the Wasatch fault, located just east of the project. That fault lies at the western base of the Wasatch range and extends the entire length of the valley. Approximately 90 percent of the entire population of Utah live within this region. While this fault has not been as active as those in California and Alaska, it poses a threat that could not be ignored.

UDOT initially hired Parsons, Brinkerhoff, Quade and Douglas (PBQ&D) to assist them in planning the project and developing the bidding documents. Included in that part of the work was the analysis of the seismic hazard that should be considered in the design. They were charged with developing seismic design criteria and construction details. PBQ&D sub-contracted with Dames & Moore to conduct an extremely comprehensive seismic hazard analysis of the entire region. The ultimate goals of that study were the development of seismic design criteria and to present methods to evaluate the liquefaction potential of soils along the I-15 corridor. The seismic source models and liquefaction methods were developed in consultation with a Seismic Advisory Committee (SAC). The SAC had been assembled by UDOT early in the process. The SAC consisted of many experts in seismology and earthquake engineering, including Jim Gates and Ken Jackura from the California DOT who had extensive recent experience in earthquake engineering as a result of several major earthquakes in that state. Also

on that team were noted geotechnical engineers and seismologists from the local area, including the three major universities in Utah.

Dames and Moore reviewed the geologic, tectonic and seismicity data for the region, developed seismic source models, and selected ground-motion attenuation equations for the seismic hazard analysis. The advisory committee agreed on the design accelerations but there was some disagreement on the attenuation relationships procedure. Three response spectra were developed to match surface conditions and the geographical locations were identified in the documents. A guidance document was provided to all three proposers prior to the receipt of the formal proposals.

After Wasatch Constructors was selected to implement the project they had to develop response spectra for the soft soils because the Dames & Moore spectra were not appropriate for other than the harder soils. (This is the similar problem that was faced in California after the Loma Prieta earthquake of 1989). Wasatch Constructors used Woodward-Clyde to do this work. A Geotechnical Oversight Committee was established during the 30 percent design phase. Ultimately, a modified seismic design procedure was developed. The UDOT staff interviewed recommended that in the future the ground motion criteria should not be developed without geotechnical assistance.

Wasatch adopted a bridge seismic design procedure that used a combination of AASHTO and ATC-32 procedures. That was considered appropriate because the ATC-32 document was developed by experts following the Loma Prieta earthquake and includes many advanced seismic design features. The ultimate design level earthquake used was a UDOT decision after advice from the SAC. They used a probabilistic approach but were convinced by Caltrans' Jim Gates to also compare this with a deterministic approach. A deterministic approach is less time consuming and much less costly than a probabilistic approach. It was felt that for most freeway type structures the probabilistic approach was not justified. The designers used a 2500-year return period for the bridges and embankments and 50-year return period for retaining walls. The AASHTO specifications require a 10% probability of exceedance in 50 years. Wasatch and UDOT used a 10% probability of exceedance in 250 years. While this is much more conservative than the AASHTO requirement it was judged to be more appropriate for Utah. For comparison the California seismic design procedures use a 1500-year return period.

Wasatch decided that all the bridges could be classified as "important bridges", a designation used by AASHTO that requires a higher level of performance. Therefore, the performance criteria is higher than most states would use for typical freeway structures. Many of the bridge designers employed by Wasatch came from recent seismic design projects in California and they were instrumental in convincing UDOT and

Wasatch management to utilize the ATC-32 recommendations for seismic design of bridges. They also utilized many details that had been used and tested on the west coast.

LESSONS LEARNED

The following is a list of some of the lessons learned so far in the use of innovative methods in the construction of the project.

MSE Walls

- Settlement of embankments in the order of two meters or more requires special consideration for deformation of the face of the embankment. This has resulted in some difficulty in attaching the second phase wall facing panel to the face of the embankment and maintaining a uniform alignment.
- Extensive settlement of the embankment can result in settlement beyond the intended limits affecting adjacent properties. Modifications to compaction procedures and material gradation were made to reduce potential settlement outside of the intended areas on this project. These modifications have resulted in satisfactory performance.

Pre-Stressed Concrete Girders

- Establishing sound quality control procedures to be followed in the fabrication of girders is essential to successfully manufacturing them. This is especially important if the type and shape of the girders is substantially different than those normally fabricated by the supplier as was the case with this project.
- Care must be taken in handling girders with thin sections due to their fragility.

Geofoam Embankments

- Geofoam blocks exhibit settlement within the blocks themselves. This internal settlement was not expected.
- The method of encapsulating the geofoam blocks using concrete load distribution slabs and granular fill material apparently is adequate to provide protection of the foam from excessive heat and fuel spills.

Lime Cement Columns

- The use of lime cement columns on this project proved to be too expensive and time consuming to be extensively used as a foundation stabilization method. It was used on a limited basis on this project even though the plan was to use it more extensively.

Pre-Cast, Stay-In-Place Forms

- Good quality control methods need to be implemented to assure uniform quality in the fabrication of panels, especially in the pre-stressing process. Care needs to be given to the methods used to release pre-stressing tendons to prevent cracking on the members.
- Use of styrofoam blocks cut to fit the roughness of the girder tops has been useful in providing a more uniform support for the panels.

Seismic Criteria

- Geotechnical engineering advice should be considered in the development of ground motion criteria to be used in the design.

Credits: The details shown on the figures are provided courtesy of Wasatch Constructors